

HIGHLY SILICIFIED EARLY DEVONIAN (EMSIAN) BRACHIOPODS FROM THE MURRINDAL LIMESTONE, BUCHAN, EASTERN VICTORIA

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VALENTINE, J. L., 2005. Silicified Early Devonian (Emsian) brachiopods from the Murrindal Limestone, Buchan, eastern Victoria. *Proceedings of the Royal Society of Victoria* 117(2): 199–264. ISSN 0035-9211.

Silicified Early Devonian (Emsian; *perbunus* Zone) brachiopods from the Murrindal Limestone of eastern Victoria are documented in their entirety for the first time. The fauna consists of 35 species, assigned to 31 genera, and shows closest faunal similarities with the brachiopod faunas of the Murrumbidgee Group of the Taemas-Wee Jasper area of New South Wales. The Murrindal Limestone brachiopod fauna is dominated taxonomically by strophomenids (five genera and five species), orthids (eight genera and eight species) and spiriferids (five genera and six species). However, the atrypids, especially *Atryparia penelopeae* (Chatterton, 1973) (784 ventral valves; 794 dorsal valves; 778 articulated specimens), dominate the fauna numerically. New taxa include the dalmanellid subfamily Bidigitinae subfam. nov. with type species *Bidigitus murrindalensis* gen. et sp. nov.; other new taxa are a dalmanellid, *Biernatium catastum* sp. nov., and a leptaenid, *Notoleptaena adamantea* sp. nov.

Keywords: Buchan, Early Devonian, Murrindal Limestone, rhynchonelliformean brachiopods, Victoria

HIGHLY diverse brachiopod faunas occur in many eastern Australian Devonian carbonate sequences. These include the Broken River Group and Ukalunda Beds of northeast Queensland (Broek 1989; Broek & Talent, 1993); the Garra Limestone (Savage 1969; Lenz & Johnson 1985a, b; Farrell 1992; Brock 2003a, b) and the Murrumbidgee Group (Chatterton 1973) of New South Wales; and the Buchan Group of eastern Victoria (Talent 1956a). However, despite having such prominence, many brachiopod faunas remain undocumented.

The Buchan Group of eastern Victoria (Fig. 1) contains some of the richest Devonian brachiopod faunas in eastern Australia. Despite being known since the 1860s (Selwyn & Ulrich 1867; McCoy 1867), only the brachiopods of the Buchan Caves Limestone have been fully documented (Talent 1956a). Very few taxa have been documented from the Taravale Formation and Murrindal Limestone (Chapman 1913; Gill 1951; Campbell & Talent 1967; Teichert & Talent 1958; Talent et al. 2000, 2001).

GEOLOGY AND STRATIGRAPHY

The Buchan Group, a 1100 m carbonate-mudstone succession, outcrops in a broad north-south synclinal structure in the Buchan-Murrindal area of east-

ern Victoria (Fig. 1) as well as at Bindi, The Basin and numerous other areas where only parts of the lowest unit, the Buchan Caves Limestone have been preserved (see Mawson 1987: figs 1–5). The Buchan Caves Limestone rests disconformably, or with minor unconformity, on the Snowy River Volcanics (Fig. 2) (Teichert & Talent 1958; Mawson 1987; Mawson et al. 1992) and is conformably overlain by the Taravale Formation (Fig. 2), a sequence of mudstones and shales with subordinate limestones tending to be nodular (Teichert & Talent 1958; Mawson 1987) and apparently deposited on a southwards sloping submarine shelf (Talent 1965a, 1969). The group reaches a thickness of around 600 m at the southern end of the Buchan Syncline. At the northern end of the Buchan Syncline, the Taravale Formation occurs as two poorly outcropping tongues of mudstone and calcareous mudstone with occasional beds of limestone and nodular limestone: the Pyramids Mudstone Member (Teichert & Talent 1958) — between the Buchan Caves Limestone and the overlying Murrindal Limestone (Fig. 2) — and an unnamed poorly outcropping tongue, referred to as the Upper Taravale Formation in Fig. 2, overlying the Murrindal Limestone and known primarily from deeply weathered exposures in road cuttings; the stratigraphy and palaeontology of this unnamed member are poorly known. The Pyramids Member

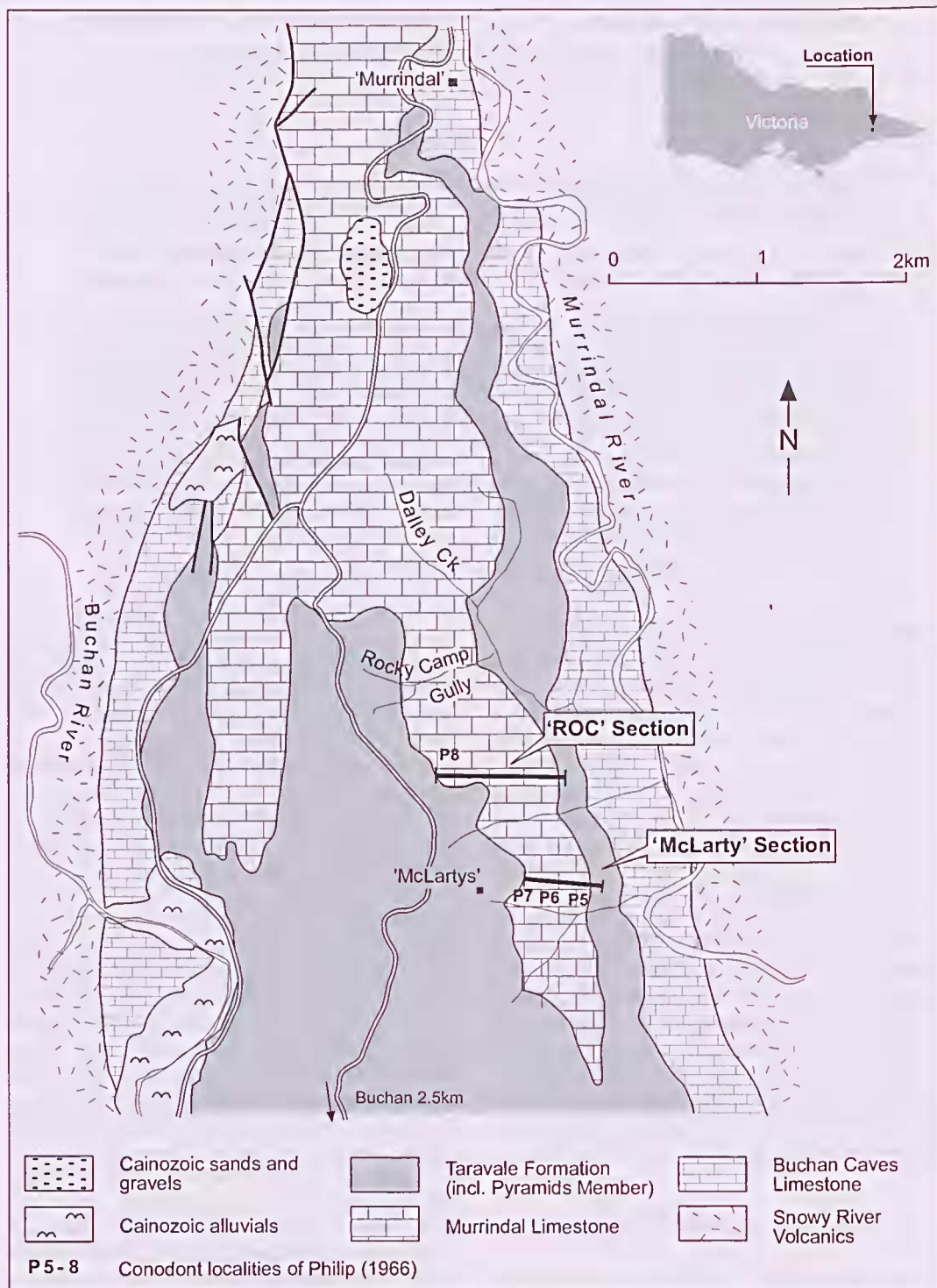


Fig. 1. The Buchan-Murrindal area, eastern Victoria (after Mawson 1987).

is occasionally highly fossiliferous, the proportion of carbonate increasing northwards until a short distance north of Murrindal State School (see Mawson 1987: fig. 1) where it can no longer be differentiated from the overlying and underlying units (Teichert & Talent 1958; Mawson 1987).

The middle part of the Taravale Formation grades laterally into the Murrindal Limestone a few kilometres north of Buchan (Fig. 2). This unit is up to 250 m thick and consists of a broad spectrum of carbonate lithologies including micrites, calcarenites, a few rudites, calcareous mudstones (especially southwards towards Moon's Road), algal mudstones and a prominent algal biostrome outcropping about 75 m above the base of the formation. Based on conodont data, it has been suggested that the Murrindal Limestone accumulated more rapidly than the deeper water nodular limestones, shales and impure limestones of the Taravale Formation (Hyland & Pyemont in Mawson et al. 1988). The wide range of carbonate lithologies accords with a situation in which there was considerable patchiness in carbonate environments (and biofacies), the areas and relationships of these fluctuating through time.

Teichert & Talent (1958) discriminated two members within the Murrindal Limestone (Fig. 2), the well-bedded, typically dark grey, McLarty Mem-

ber representing shallow shelf, but not intertidal carbonate environments, and the less well-bedded, paler grey limestones of the Rocky Camp Member, interpreted as being biohermal in origin (Mawson 1987; Wallace 1987; Holloway 1996). These build-ups are now interpreted as carbonate mud-mounds (Wallace 1987).

PREVIOUS WORK

The presence of limestone outcrops in the Buchan-Murrindal area of eastern Victoria was first mentioned by Selwyn & Ulrich (1867) who believed they may have been Devonian in age, based on McCoy's (1867) identification of *Spirifera laevicosta* (Valeneiennes in Lamarek, 1819) (species name misspelled *laevicostata* until Chapman's (1905) review of the species), a Middle Devonian brachiopod occurring in the Eifel Hills of western Germany. McCoy (1876) described in detail the first fossils from the Buchan limestones which included *Favosites goldfussi* d'Orbigny, 1850, *Spirifera laevicosta*, *Chonetes australis* McCoy, 1876, *Phragmoceraceras subtrigoumum* McCoy, 1876, and *Asterolepis ornatus* var. *australis* McCoy, 1876. The first geological survey of the area was undertaken by Howitt (1876: 203), who described the Buchan limestones as being compact and dark blue to almost black limestone deposited some distance from land in seas of moderate depth. Howitt (1876) accepted McCoy's (1867) view that the Buchan limestones were Middle Devonian, an assessment not seriously challenged until the 1960s.

During the 1940s, Teichert undertook the first detailed study of the geological structure and stratigraphy of the Buchan-Murrindal area and is primarily responsible for the stratigraphic nomenclature that came to be applied to what was formerly referred to as the 'Buchan Limestones'. The lowest unit he termed the Cave Limestone (Teichert 1948), subsequently amended to Buchan Caves Limestone to avoid confusion with similarly named units elsewhere in Australia. He initially regarded the overlying limestone-mudstone sequence as consisting of two units, the Lower Murrindal Beds — with the goniatite *Gyroceratites* von Meyer, 1831 and baetritid *Lobobactrites* Schindewolf, 1932 — and the Upper Murrindal Beds. This nomenclature was used by Hill (1950) when describing corals collected by Teichert and sent to her for identification.

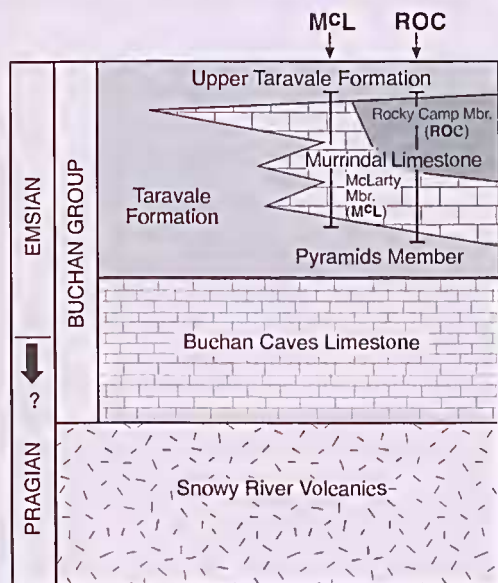


Fig. 2. Stratigraphy of the Buchan district showing the two sections, McL and ROC, through the Murrindal Limestone sampled for brachiopods (not to scale) (after Mawson 1987 and Holloway 1996).

Teichert & Talent (1958) provided a comprehensive account of the geology and stratigraphy of the post-Snowy River Volcanics sequence of the Buchan area and, on the basis of extensive collections, provided the first overview of the abundant and diverse fossil assemblages occurring at many horizons throughout the Buchan Group. Since then, several groups have received additional attention: fish remains (Long 1984, 1986; Burrow & Turner 1998; Basden 1999), conodonts (Mawson 1987; Hyland & Pyemont in Mawson et al. 1988; Pyemont 1990; Mawson et al. 1992), chitinozoans (Winchester-Seeto & Paris 1989; Winchester-Seeto 1996), bivalves (Johnston 1993), stromatoporoids (Webby et al. 1993), trilobites (Holloway 1996), foraminifers (Bell 1996; Bell & Winchester-Seeto 1999), daeryoconarids (Alberti 1993, 1995) and disarticulated erinoid remains (Stukalina & Talent unpubl. data).

Teichert & Talent (1958) believed the Buchan Group to be early Middle Devonian in age, with the possibility that the Buchan Caves Limestone extended down into the latest part of the Early Devonian. This assessment was based primarily on the presence of the bactritid, *Lobobactrites* and goniatite, *Gyroceratites* (Teichert 1948) from the Taravale Formation, and to a lesser extent on the presence of the trilobites *Harpes* Goldfuss, 1839 and *Scutellum* Puseh, 1833 in the uppermost parts of the Buchan Group. Hill's (1950) opinion, based on tabulate and rugose corals, was in accord with this assignment.

Erben (1960, 1962, 1964, 1965), Chlupáč (1976) and House (1979) reconsidered the identity of the goniatites described by Teichert (1948) and, *inter alia*, proposed several new genera including two from Buchan, *Teicherticeras* Erben, 1960 (an Emsian form) and, subsequently, *Talenticeras* Erben, 1965. This, together with subsequent work on other groups including conodonts (Philip & Pedder 1964; Philip 1966), triggered realization that some, if not all, of the sequence was late Early Devonian (Emsian) in age.

The pioneering conodont work of Philip & Pedder (1964) and Philip (1966) has now been superseded by conodonts from several hundred samples collected from measured stratigraphic sections (often bed-by-bed sampling; present database > 10,000 conodonts, Mawson pers. comm.) through all units of the Buchan Group in the Buchan-Murrindal area and from Bindi, The Basin, Dead Horse Creek, and Boulder Flat, as well as spot sampling in

several other areas (Mawson 1987; Mawson et al. 1988, 1992; Pyemont 1990). This work not only provided tightly constrained ages for all units of the Buchan Group, but conodont data through the goniatite-bearing intervals low in the Taravale Formation suggest these may be the oldest ammonoids in the world (Mawson 1987). Conodont studies of Mawson (1987) and Mawson et al. (1988, 1992) indicated that the Buchan Caves Limestone belongs to the *dehiscens* Zone (but not latest *dehiscens* Zone), possibly extending down into the *pireneae* Zone (uppermost zone of the Pragian); the Taravale Formation spans the interval from late *dehiscens* Zone through to somewhere in the *serotinus* Zone (late Emsian); the Pyramids Mudstone Member of the Taravale Formation is late *dehiscens* Zone to early *perbonus* Zone; and the Murrindal Limestone extends from early, but not earliest, *perbonus* Zone, through to just before the base of the *inversus* Zone (Mawson et al. 1988: 498–499, table 8).

Bed-by-bed sampling for conodonts along McLarty's Ridge (Fig. 1) undertaken by Mawson, Talent and Hyland embraced the uppermost 62 m of the Pyramids Member of the Taravale Formation, 158 m of the Murrindal Limestone and finished low in the upper, unnamed tongue of Taravale Formation (Fig. 4). Of the 3388 conodonts recovered, *Polygnathus perbonus* (Philip, 1966) and *P. nothoperbonus* Mawson, 1987, were present from the first to the last beds sampled, indicating that the entire section lies within the *perbonus* Zone. A similar exercise conducted along Rocky Camp Ridge (Fig. 1) provided materials for Pyemont's (1990) dissertation. This section commenced 17 m below the base of the Murrindal Limestone and passed through 147.5 m of the Murrindal Limestone and ended very low in the upper tongue of Taravale Formation (Fig. 3). It yielded 1922 conodonts of which *P. perbonus* and *P. nothoperbonus* were dominant; this section too lay entirely within the *perbonus* Zone.

No chitinozoans were obtained from the Murrindal Limestone, but the Taravale Formation — more pelagic as indicated by goniatite and daeryoconarid faunas — produced 55 species of chitinozoans grouped in seven assemblages (Winchester-Seeto & Paris 1989; Winchester-Seeto 1996), that appear to have only local stratigraphic application. Fifteen of the reported species are new and a further 15 are probably new. Only five species have tentative relationships with Emsian species from Europe (see Winchester-Seeto 1996: 159–160).

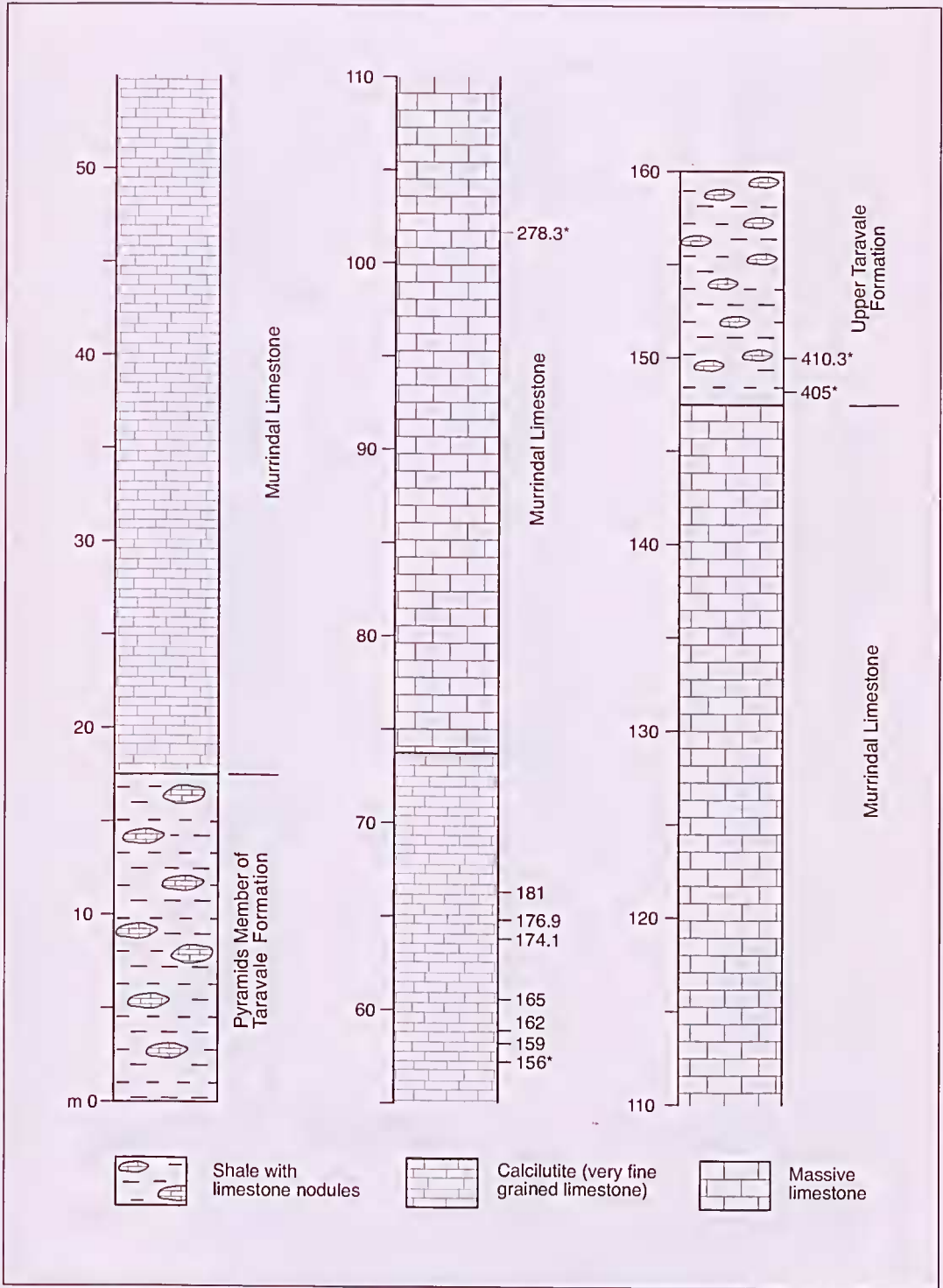


Fig. 3. ROC stratigraphic section (*perbonus* Zone). Numbers on the right hand side of columns indicate silicified horizons from which brachiopods were collected. Those with an asterisk indicate non-silicified horizons.

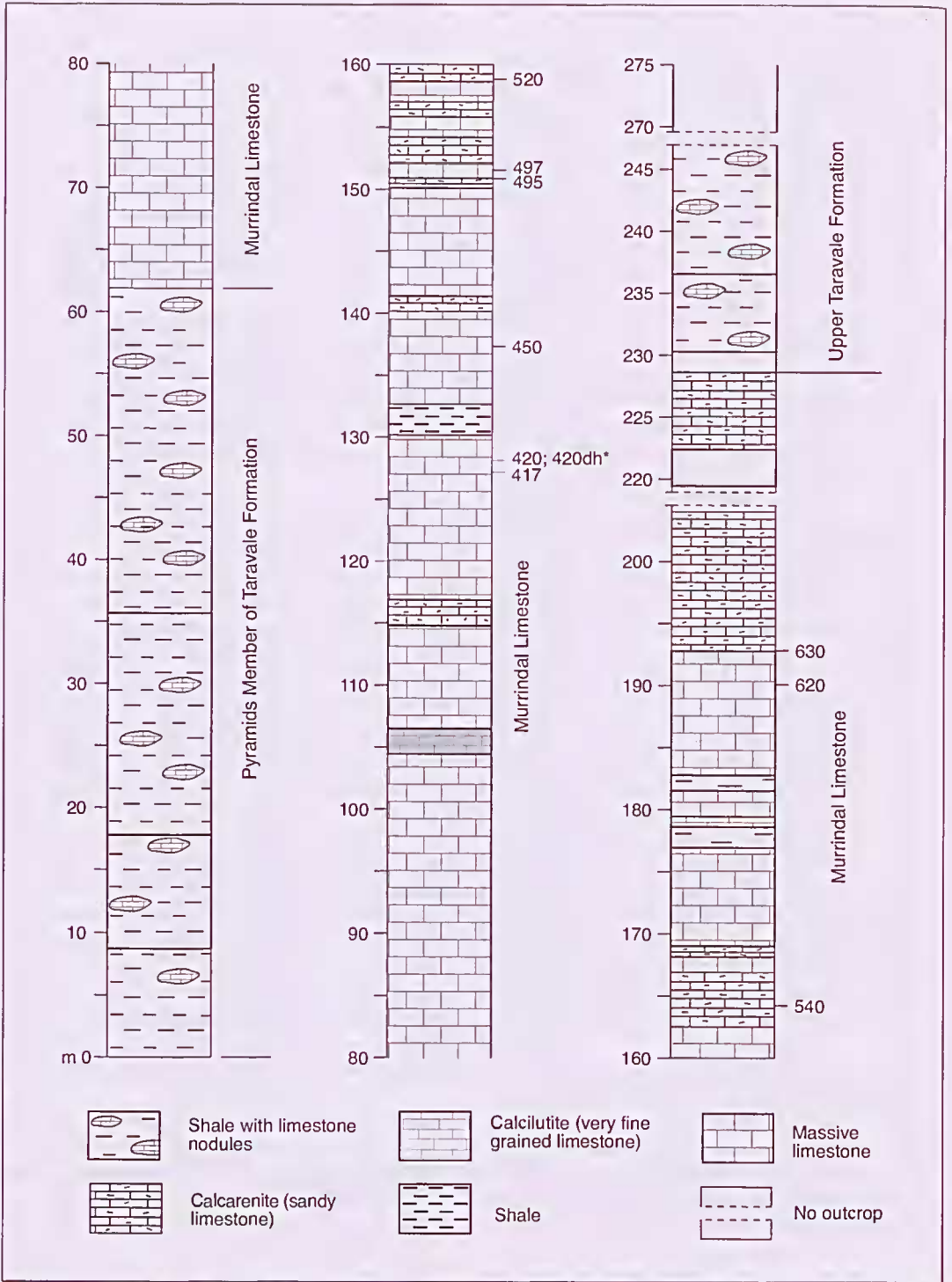


Fig. 4. McL stratigraphic section (*perbonus* Zone) (after Hyland & Pyemont in Mawson et al. 1988). Numbers on the right hand side of columns indicate silicified horizons from which brachiopods were collected. (*dh = down hill).

Brachiopod taxa	ROC 156		ROC 159		ROC 162		ROC 165		ROC 174.1		ROC 176.9		ROC 179		ROC 278.3		ROC 405		ROC 410.3	
	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv	vv	dv
<i>Opizicoidon areticon</i>																				
<i>Opizicoidon</i> sp. cf. <i>O. allridgii</i>																				
<i>Cronops australis</i>																				
<i>Nonolepisma adamantea</i> sp. nov.	2	3			34	17	5	4	7	3	1	3	4	1						
<i>Cyrcostrophia (Procyrcostrophia) dickinsi</i>	11	2	3		5			7	5	1		3	2	2					16	9
<i>Maturostrophia</i> sp. cf. <i>M. jabellicauda</i>	9	2	1		5							1	1	1						
<i>Nadurostrophia parsoni</i>	2	1										1	1	1						
<i>Mesoleptostrophia (Paroleptostrophia) Yelarkai</i>	19	3	4		4		1					4	1						3	
<i>Lehaconetes australis</i>	6	4	5		9			15	7	1		2	1						5	
<i>Lehaconetes</i> ? sp. cf. <i>L. calleni</i>					1		3													3
<i>Zoschuchersella murphyi</i>																				
<i>Dolerorites</i> sp.	1				4	1	3													
<i>Hesperorthis</i> gen. et sp. undet.																				
<i>Tyrsella spidens</i>	88	82	1		71	51	6	5		35	42	5	8	17	1				15	21
<i>Prokopia hillae</i>																				
<i>Reaserella curayi</i>	150	79	46		218	139	87	25	9	17	79	47	4	19	9	2	1	12	28	11
<i>Bidignis murrindalensis</i> gen. et sp. nov.	5	4			40	17		3	1	9	2			2	2				13	4
<i>Aulacella philipi</i>	4	3	1		3			1	5	73										1
<i>Engelstinoisochia linki</i>																				
<i>Pugnax</i> ? <i>uepiki</i>	2	6	37		9			4	10					28	1	9				10
<i>Spinella buchamensis buchamensis</i>					3															
<i>Spinella yasensis</i>	1				4															
<i>Howellia (Howellia) textilis</i>																				
<i>Howellia howitti</i>	2	1	1		2	3														
<i>Cyrtina wellingtonensis</i>					1			21	19	9	32									2
<i>Atrypana pendlopa</i>	28	18	57		506	520	458	25	21	91	7	1	1	25	27	12	1	4	82	83
<i>Variatrypa (Variatrypa) Yerecstrois</i>					41	18	72	3	2	19				5	5	1	3	6	8	4
<i>Buchanadyris westoni</i>	20	28	6		105	109	9	10	3	6	3			15	18		6	5	11	9
<i>Mifedus shandhykdi</i>					5															2
<i>Mifedus</i> ? <i>glaber</i>					1															

Table 1. Stratigraphic distribution of brachiopods collected from the ROC section (*perbonus* Zone) through the Murrindal Limestone, Buchan, Victoria. Abbreviations: vv = ventral valve; dv = dorsal valve; a = articulated specimen.

Brachiopod taxa	MFL 417		MFL 420		MFL 420dh		MFL 450		MFL 495		MFL 497		MFL 520		MFL 540		MFL 620		
	vv	dv	a	a	vv	dv	a	vv	dv	a	vv	dv	a	vv	dv	a	vv	dv	a
<i>Craniojps australis</i>	5	2	1										1						
<i>Notoleptaena adamanica</i> sp. nov.	3	1							1										
<i>Cymostrophia (Protoacynostrophia) dickinsi</i>	2				12	7	1						6	2	3				
<i>Malacostrophia</i> sp. cf. <i>M. jubbeliccauda</i>													1						
<i>Nadiastrophia palmorae</i>					1		3		1				2						
<i>Mesoleptostrophia (Puraleptostrophia) clarkae</i>	3												2						
<i>Johnsonetes australis</i>			2				4						1						
<i>Eoschuchertella murphyi</i>	1												1						
<i>Dolerorthis</i> sp.	19	23	4		5	7							17						
<i>Tyrsocella spidont</i>	1												3	9					
<i>Prokopia hillae</i>	60	24	10		4	4	1						4	1					
<i>Resserella curcyi</i>	7	4	1										7	1	1				
<i>Bigligus murrindalensis</i> gen. et sp. nov.													13	20	1				
<i>Biernatium calastium</i> sp. nov.	5	10	1		27	40							9	24	2				1
<i>Aulacella philipi</i>			2										1						
<i>Eoglossinotocella linki</i>	4	2	137										3						
<i>Trigona? oepiki</i>	5	3			2														
<i>Spinella buchanensis buchanensis</i>	2																		
<i>Spinella yassensis</i>	3	3																	
<i>Ambocella</i> sp. aff. <i>A. runnegari</i>													2	1	3				
<i>Dolhyris?</i> sp.																			
<i>Howellella (Howellella) rextilis</i>	31	19	4		5	2	3						4						
<i>Howittia howitt</i>	3												5	4	6				
<i>Cyrtina wellingtonensis</i>	12	4	16		2	1							49	38	83				
<i>Atryparia penelopeae</i>	105	115	109		1								1	3					2
<i>Variatrypa (Variatrypa) erectrostris</i>	8	1	8																
<i>Coelospira duy</i>	41	36	1		3	2							1	5	12				
<i>Buchanathyrus westoni</i>																			
<i>Nucleospira</i> sp.	1	11			1	1			2										
<i>Micidius shandkyvldi</i>																			
<i>Micidius? glaber</i>																			17

Table 2. Stratigraphic distribution of brachiopods collected from the McL. section (*perbomus* Zone) through the Murrindal Limestone, Buchan, Victoria. Abbreviations as for Table 1.

SYSTEMATIC PALEONTOLOGY

Brachiopods for this project were collected from silicified horizons along the Rocky Camp Ridge (ROC) and McLarty Ridge (McL) sections through the Murrindal Limestone (Figs 1, 3, 4, Tables 1, 2). All type and figured material is lodged in the palaeontological collections of the Australian Museum (AM F).

Phylum BRACHIOPODA Duméril, 1806

Remarks. Unless otherwise mentioned, the higher level classification used herein follows that of Kaesler (2000, 2002).

- Subphylum LINGULIFORMEA Williams, Carlson, Brunton, Holmer & Popov, 1996
- Class LINGULATA Gorjansky & Popov, 1985
- Order ACROTRETIDA Kuhn, 1989
- Superfamily ACROTRETOIDEA Schuchert, 1893
- Family BIERNATIDAE Holmer, 1989

Opsiconidion Ludvigsen, 1974

Type species. By original designation of Ludvigsen (1974: 143); *Opsiconidion arcticon* Ludvigsen, 1974; early Emsian of the Michelle Formation, Yukon Territory, Canada.

Remarks. *Opsiconidion* is one of only six known genera of post-Ordovician acrotretid brachiopods (Krause & Rowell 1975; Biernat & Bednarczyk 1990; Brock et al. 1995; Mergl 2001) and ranges from Ordovician (Ashgill) to Middle or ?Upper Devonian (Holmer & Popov 2000). Brock et al. (1995) documented four species of *Opsiconidion* from New South Wales and Victoria ranging from the Lochkovian (*pesavis* Zone) to Emsian (*dehiscens* Zone). Brock et al. (1995) also reported the presence of three poorly preserved dorsal valves from the Middle Devonian Yarranie Formation of New South Wales. These were questionably referred to *O. minor* Popov, 1981a, possibly extending the stratigraphic range of this genus in Australia to the Givetian (*varvus* Zone). However, additional material is required to confirm this.

Opsiconidion arcticon Ludvigsen, 1974
Fig. 5A-C

Opsiconidion arcticon Ludvigsen 1974: 145, fig. 4, 1-3; fig. 5, 1-8.-von Bitter & Ludvigsen 1979: 707, pl. 90, figs 1-12; pl. 91, figs

1-12.-Brock, Engelbretsen & Dean-Jones 1995: 111, figs 4A-F.-Brock 2003a: 104, pl. 1, figs 8-13, 15-16.

Material. Figured material: AM F117236 (Fig. 5A, B): ventral valve from sample ROC 156; AM F117237 (Fig. 5C): dorsal valve from sample ROC 156. Unfigured material: one dorsal valve.

Description. See Ludvigsen (1974: 145) and von Bitter & Ludvigsen (1979: 707).

Remarks. *Opsiconidion arcticon* was first documented in Australia by Brock et al. (1995: 111) from various Early Devonian localities in New South Wales and Victoria. The presence of *O. arcticon* in the ROC section of the Murrindal Limestone extends its stratigraphic range in Australia from the Pragian (*kindlei* Zone) into the Emsian (*perbonus* Zone). *Opsiconidion arcticon* has otherwise been recovered from the Lochkovian Garra Limestone at Eurimbla (Brock 2003a), the Emsian Michelle Formation in the Yukon Territory of Canada (Ludvigsen 1974) and the Lower and Middle Devonian Bois Blanc, Onondaga and Dundee Formations of Ontario (von Bitter & Ludvigsen 1979).

As outlined by Brock et al. (1995) and Brock (2003a), the diagnostic features of *Opsiconidion* are the morphology of the dorsal valve pseudointerarea and to a lesser extent, the outline of the dorsal valve. The dorsal valve pseudointerarea of *O. arcticon* is crescentic and lacks a median plate, whereas the dorsal valve outline is almost circular (Fig. 5C). *Opsiconidion* sp. cf. *O. aldridgei* (Cocks, 1979), from various Early Devonian localities in New South Wales and Victoria (see Brock et al. 1995: 111 and Brock 2003a: 104), has a less well rounded dorsal valve and a dorsal valve pseudointerarea with a straight anterior margin and a well defined median plate. *Opsiconidion minor* from the Emsian of Valnov Island, Novaja Zemlja (Popov 1981a) and various localities in New South Wales and Victoria (see Brock et al. 1995: 113), differs in having an acutely subtriangular dorsal valve pseudointerarea, a well-defined median plate and propareas and a less well-rounded dorsal valve. *Opsiconidion robustum* Brock, Engelbretsen & Dean-Jones, 1995 from the Early Devonian of New South Wales (see Brock et al. 1995: 114) is distinguished by its external ornament of well defined concentric fila, squat, conical and robust ventral valve, straight dorsal valve pseudointerarea and sub-polygonal dorsal valve outline.

Opsiconidion sp. cf. *O. aldridgei* (Cocks, 1979)
Fig. 5D, E

?*Caenotreta aldridgei* sp. nov. Cocks 1979: 96, pl. 13,
figs 1–7; pl. 14, figs 1–4.

?*Caenotreta celloni* sp. nov. Cocks 1979: 98, pl. 14,
figs 6–8.

Opsiconidion sp. cf. *O. aldridgei*-Broek, Engelbretsen & Dean-Jones 1995: 111, fig. 5A-K.-
Broek 2003a: 104, pl. 1, fig. 14.

Material. Figured material: AM F117238 (Fig. 5D):
dorsal valve from ROC 410.3; AM F117239 (Fig.
5E): dorsal valve from ROC 410.3.

Description. See Cocks (1979: 96).

Remarks. The dorsal valve pseudointerarea of *O. aldridgei* is short and wide, with a straight anterior edge and a well-defined median plate. The dorsal valve is subcircular in outline (Cocks 1979; Brock et al. 1995). Brock et al. (1995) and Brock (2003a) differentiated between *O. sp. cf. O. aldridgei* from various Early Devonian localities in New South Wales and Victoria (see Brock et al. 1995: 111 and Brock 2003a: 104) and *O. aldridgei* from the Llandovery of the Welsh Borderlands (Cocks 1979), the Llandovery to Wenlock of Saaremaa, Estonia (Popov 1981b) and the Boree Creek Formation of central-western New South Wales (Valentine et al. 2003), because the median plate of the Early Devonian specimens is less distinct. The Murrindal specimens are most similar to those described by Brock et al. (1995) and Brock (2003a). This extends the stratigraphic range of the *O. sp. cf. O. aldridgei* from the Pragian (*kindlei* Zone) to the Emsian (*perbonus* Zone).

Opsiconidion praecursor Popov, Nölvak & Holmer, 1994, from the Upper Ordovician Harju Series of southern Estonia, is very similar to *O. aldridgei*. The dorsal valve outline of both species is subcircular and both have an anacline pseudointerarea with a straight anterior margin. *Opsiconidion praecursor* differs in being smaller, having a relatively smaller dorsal valve pseudointerarea and pos-

sessing large larval pits surrounded by clusters of smaller ones (Popov et al. 1994).

Opsiconidion arcticon, from various Early Devonian localities in New South Wales and Victoria (see Brock et al. 1995: 111 and Brock 2003a: 104), the Emsian Michelle Formation in the Yukon Territory of Canada (Ludvigsen 1974), and the Lower and Middle Devonian Bois Blanc, Onondaga and Dundee Formations of Ontario (von Bitter & Ludvigsen 1979), possesses a similar ventral valve to *O. sp. cf. O. aldridgei*, but the latter has a slightly flattened pseudointerarea. The dorsal valve of *O. arcticon* has a more circular outline and crescentic pseudointerarea. *Opsiconidion minor*, from the Emsian of Valnov Island, Novaja Zemlja (Popov 1981a) and also recovered by Brock et al. (1995: 113) from various Early Devonian localities in New South Wales and Victoria, differs in having an acutely subtriangular pseudointerarea and a well-defined median plate. *Opsiconidion robustum* from the Early Devonian of New South Wales and Victoria (Brock et al. 1995: 114) is distinguishable by its external ornament of well-defined concentric fila, its squat, conical and robust ventral valve and sub-polygonal dorsal valve outline.

Subphylum CRANIIFORMEA Popov, Bassett,
Holmer & Laurie, 1993
Class CRANIATA Williams, Carlson, Brunton,
Holmer & Popov, 1996
Order CRANIOPSISIDA Gorjansky & Popov, 1985
Superfamily CRANIOPSOIDEA Williams, 1963
Family CRANIOPSISIDAE Williams, 1963

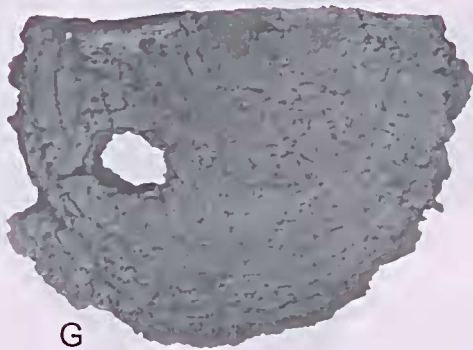
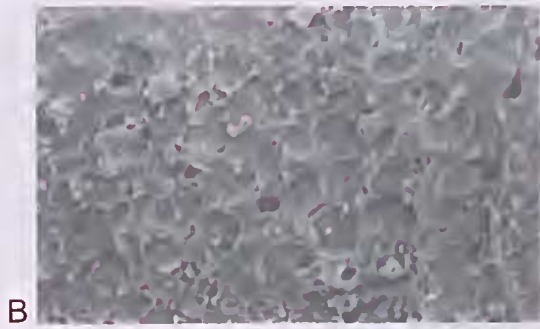
Craniops Hall, 1859a

Type species. By original designation of Hall (1859a: 84); *Orbicula? squamiformis* Hall, 1843; Lochkovian of the Helderberg Group, New York, America.

Craniops australis Chatterton, 1973
Fig. 5F-H

Craniops australis sp. nov. Chatterton 1973: 17, pl. 1,
figs 1–7; pl. 5, figs 26–30.

Fig. 5. A–C, *Opsiconidion arcticon* Ludvigsen, 1974. A, B, ventral valve lateral view, x 120, close up of ventral valve larval shell pitting x 2670, ROC 156, AM F117236. C, dorsal valve interior, ROC 156, AM F117237, x 94. D, E, *Opsiconidion* sp. cf. *O. aldridgei* (Cocks, 1979). D, dorsal valve interior in lateral oblique view, ROC 410.3, AM F117238, x 69. E, dorsal valve interior in lateral oblique view, ROC 410.3, AM F117239, x 69. F–H, *Craniops australis* Chatterton, 1973. F, ventral valve interior, ROC 176.9, AM F117240, x 37. G, ventral valve exterior, ROC 176.9, AM F117241, x 33. H, dorsal valve interior, ROC 159, AM F117242, x 37.



Material. Figured material: AM F117240 (Fig. 5F): ventral valve from ROC 176.9; AM F117241 (Fig. 5G): ventral valve from ROC 176.9; AM F117242 (Fig. 5H) dorsal valve from ROC 159. Unfigured material: ten ventral valves, seven dorsal valves and two complete specimens.

Description. See Chatterton (1973: 17).

Remarks. *Craniops australis* from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas and the Murrindal Limestone at Buchan, differs in several ways from the *C. squamiformis*. *Craniops squamiformis* has a thinner shell, a more subquadrate outline and finer, more numerous and closely spaced growth lines. The apex of *C. australis* is located closer to the posterior margin than the apex of *C. squamiformis*. Hall (1859a) also mentioned the presence of fine radiating striae crossing the lamellae in well-preserved specimens of *C. squamiformis*, as does Chatterton (1973) for some specimens of *C. australis*. However, Chatterton's (1973: pl. 1, figs 1-7; pl. 5, figs 26-30) figured material show no trace of radial striae, nor do any of the Murrindal specimens (Fig. 5G).

Craniops australis is the only definite occurrence of this genus in Australia. A questionable occurrence was reported by Strusz (1982) from the Wenlock Walker Volcanics near Canberra. Though externally resembling *Craniops*, this assignment is tentative owing to a lack of material showing sufficient detail of internal features and doubts over the presence of an attachment scar (Strusz 1982).

Craniops australis appears most closely related to *Craniops* sp. 1 of Perry (1984) from the late Emsian of the Delorme Formation of western Canada. Although both are similar in terms of outline, ornament and muscle scar impressions, the Delorme specimens possess a much more prominent attachment scar. *Craniops patina* (Hall & Clarke, 1893) from late Emsian beds of the Bois Blanc Formation of Ontario is externally similar to *C. australis*; the two species also possess similar muscle scar impressions. They differ most notably in that the dorsal

valve of *C. patina* possesses a median ridge located between the anterior adductor scars.

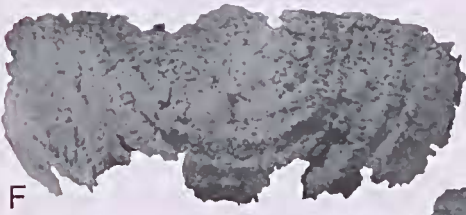
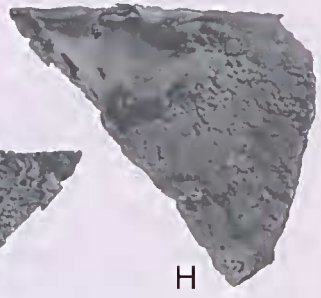
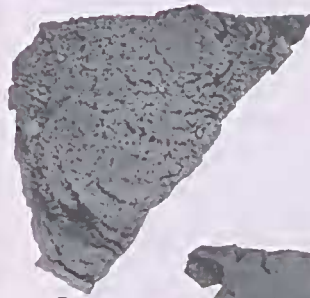
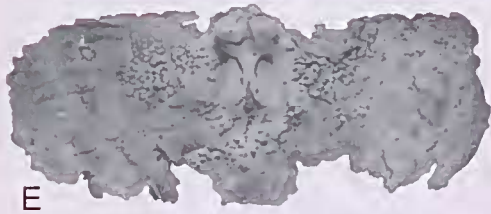
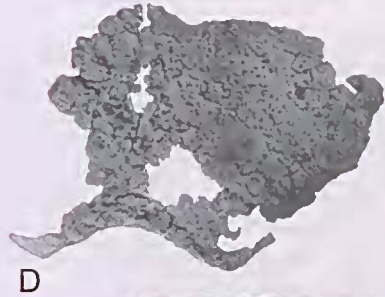
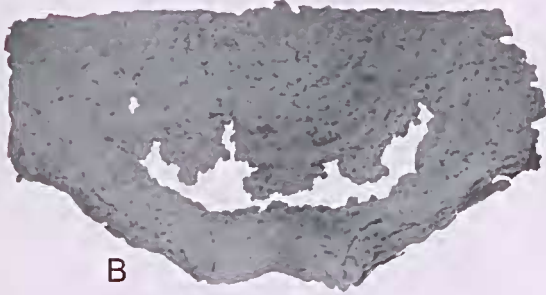
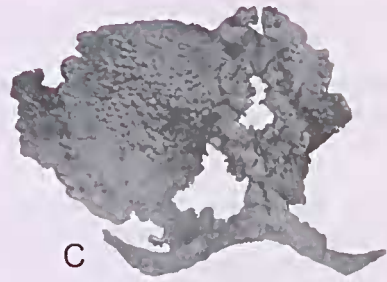
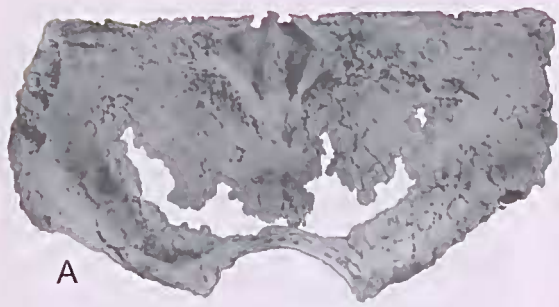
Subphylum RHYNCHONELLIFORMEA Williams, Carlson, Brunton, Holmer & Popov, 1996
Class STROPHOMENATA Williams, Carlson, Brunton, Holmer & Popov, 1996
Order STROPHOMENIDA Öpik, 1934
Superfamily STROPHOMENOIDEA King, 1846
Family RAFINESQUINIDAE Schuchert, 1913
Subfamily LEPTAENINAE Hall & Clarke, 1894

Notoleptaena Gill, 1951

Type species. By original designation of Gill (1951: 191); *Notoleptaena linguifera* Gill, 1951; Lochkovian-Pragian, Stoddart Member of the Mount Ida Formation, Heathcote-Redcastle district, Victoria, Australia.

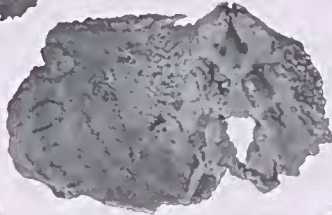
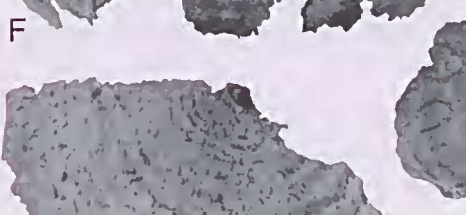
Remarks. Apart from one species left under open nomenclature by Pajchlowa (1957) from the Devonian deposits of the eastern part of the Bodzentyn synclinal outcrops in the region of Grzegorzowice and Skaly, Poland, all occurrences of *Notoleptaena* are restricted to Australia. However, as Pajchlowa (1957) neither figured nor described this specimen, no comparisons are possible. The type species has been recovered from the Lochkovian-Pragian of the Stoddart Member of the Mount Ida Formation (Mawson & Talent 2000), and *N. cf. linguifera* occurs in the Pragian Garra Limestone at Wellington (Lenz & Johnson 1985a), but has since been referred to *Glossoleptaena* Havlíček, 1956 by Broek (2003a). *Notoleptaena otophera* Gill, 1951 is widely distributed, having been recovered from the Lochkovian-Pragian Mount Ida Formation unit 3 (*Pleurodictyum* Beds), the Lochkovian Humevale Formation and the latest Lochkovian Boola Siltstone of Victoria. *Notoleptaena* aff. *otophera* occurs in the ?early Lochkovian Maradana Shale of New South Wales (Savage 1974). A third species, *N. undulifera* Talent, 1956b occurs in the Pragian Tabberabbera Formation of Victoria. *Notoleptaena adamantea* extends the stratigraphic range of this genus into the Emsian (*perbomus* Zone).

Fig. 6. A-L *Notoleptaena adamantea* sp. nov. All specimens x 2. A, B, holotype, ventral valve interior and exterior, ROC 181, AM F117243. C, D, dorsal valve interior and exterior, ROC 159, AM F117244. E, F, dorsal valve interior and exterior, ROC 181, AM F117245. G, H, ventral valve exterior and interior, ROC 159, AM F117246. I, dorsal view of articulated specimen, ROC 181, AM F117247. J, dorsal valve interior, ROC 165, AM F117248. K, L, ventral valve exterior and interior, ROC 165, AM F117249.

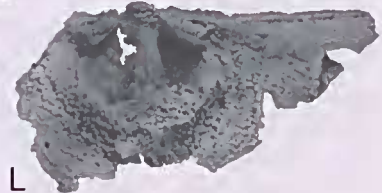
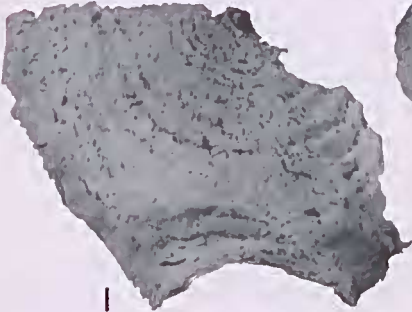


G

H



K



Notoleptaena adamantea sp. nov.

Fig. 6A-L

Etymology. L., *adamantea*, like a diamond; in reference to the diamond shaped muscle field of the ventral valve.

Diagnosis. *Notoleptaena* with diamond-shaped ventral valve muscle field, surrounded by strong muscle bounding ridges. Hinge line faintly denticulate for most of length. Delthyrium trapezoidal.

Type material. Holotype: AM F117243 (Fig. 6A, B): ventral valve from ROC 181. Figured paratypes: AM F117244 (Fig. 6C, D): dorsal valve from ROC 159; AM F117245 (Fig. 6E, F): dorsal valve from ROC 181; AM F117246 (Fig. 6G, H): ventral valve from ROC 159; AM F117247 (Fig. 6I): articulated specimen from ROC 181; AM F 117248 (Fig. 6J): dorsal valve from ROC 165; AM F117249 (Fig. 6K, L): ventral valve from ROC 165. Unfigured paratypes: 75 ventral valves, 28 dorsal valves and 17 articulated specimens.

Type locality and horizon. ROC section (sample ROC 181), Emsian (*perbonus Zone*) Murrindal Limestone, Buchan Group, Buchan, Victoria, Australia.

Description. Semicircular outline, maximum width at, or slightly forward of, hinge line. Up to twice as wide as long. Cardinal extremities variably alate. Visceral region of ventral valve convex; medial region slightly concave. Raised lateral margins, increasing in height anteriorly until reaching strongly dorsally deflected tongue. Visceral and medial regions of dorsal valve planoconvex, valve margins concave. Ornament consisting of weakly to strongly developed and irregularly spaced concentric rugae, 0.7 mm up to 2.8 mm (averaging 1.1 mm) apart. No micro-ornament observed.

Ventral valve interarea steeply apsaeline. Delthyrium trapezoidally shaped. Pseudodeltidium absent. Dorsal valve interarea small, anaeline and triangular. Notothyrium narrowly triangular, with small, fragile chilidium.

Ventral valve interior with well developed, elongately oval and crenulate teeth lying subparallel to hinge line. A broad median ridge begins one quarter to halfway across muscle field, rapidly increasing in height, and slightly in width, anteriorly. Muscle field diamond shaped and strongly excavated. Diductor sears triangular and separated by median ridge. Ad-

ductor sears long, narrow, and located on median ridge. Adductor sears may be divided anteriorly by a low, narrow ridge (0.2 mm wide), located on surface of median ridge. Muscle field bounded laterally and anteriorly by strong muscle bounding ridges that begin slightly forward of teeth. Initially divergent, muscle bounding ridges quickly and sharply turn inwards, rapidly gaining height. Height decreases towards median ridge, but increases again upon joining with median ridge. A rounded peak may be formed where muscle-bounding ridges meet. A sub-peripheral ridge extends around valve edge, joining with dorsally directed tongue anteriorly. Hinge line faintly denticulate for most of length. Inner surface pseudopunctate, especially adjacent to muscle bounding ridges. Faint impressions of external rugae may also be visible.

Dorsal valve interior with erect and strongly bilobed cardinal process. Each lobe of cardinal process oval in cross-section and in some specimens with faint striations along their elongately flattened posterior edge. Sockets shallow, triangular impressions lying adjacent to cardinal process. Subtriangular median ridge short and low, extending forward from cardinal process, rapidly narrowing anteriorly; anterior point of median ridge extended in some specimens and in one bifurcates anteriorly. Adductor sears subcircular, deeply impressed, and separated by median ridge. Two low, broad and gently arcuate anderia diverge forward from medial portion of cardinal process at 100° and extend anteriorly slightly further than median ridge before fading out. Hinge line faintly denticulate. Inner surface coarsely pseudopunctate, especially adjacent to and on anderia. Traces of rugae visible internally around valve edges.

Ventral valves		Dorsal valves	
width (mm)	length (mm)	width (mm)	length (mm)
42*		38*	
42*		32*	18
38*	15		14.5
38*		29*	
36*		22*	
34*	16	22*	
32*	21		
31.5	16		
31	12		
28*	17		
25*			

Table 3. Dimensions for *Notoleptaena adamantea* sp. nov. * Indicates dimensions estimated due to incomplete nature of recovered specimens.

Measurements. Dimensions are given in Table 3. Ventral valves average 34.3 mm in width and 16.2 mm in length. Dorsal valves average 28.6 mm in width and 16.3 mm in length.

Remarks. The specimens from the Murrindal Limestone conform to the diagnosis provided by Gill (1951) and Cocks & Rong (2000) for *Notoleptaena*. Generically diagnostic features include a dorsally directed tongue, the muscle field of the ventral being bounded laterally and anteriorly by strong muscle bounding ridges, a subperipheral ridge in the ventral valve, the presence of concentric rugae and a small dorsal valve muscle field. However, unlike previously described species of *Notoleptaena*, this species differs in having irregularly spaced concentric rugae (Fig. 6B, F, G, I, K), a diamond shaped muscle field in the ventral valve muscle field with triangular shaped diductor scars and a faintly denticulate hinge line (Fig. 6A, H, J, L).

Notoleptaena adamantea is further distinguishable from *N. linguifera* and *N. undulifera* by lacking any trace of radial costellae (Fig. 6B, F, G, I, K) or a pseudodeltidium (Fig. 6A, H, L), which may also be lacking in *N. otophera*. *Notoleptaena linguifera* differs further in possessing more strongly developed rugae. *Notoleptaena adamantea*, unlike *N. undulifera* and *N. cf. linguifera*, also possesses well-developed teeth (Fig. 6A, H, L). Whereas *N. linguifera* also possesses well-developed teeth, they lack the crenulations present on the teeth of *N. adamantea* (Fig. 6A, H, L). Dorsal valve interiors are known only for *N. undulifera*, *N. linguifera* and *N. cf. linguifera*; these species and *N. adamantea* all possess a similar cardinal process, but the subtriangular median ridge of *N. adamantea* distinguishes it from the other three taxa (Fig. 6C, E, J).

An unnamed species of *Notoleptaena* from the Lochkovian Bell Shale of the Eldon Group of Tasmania was described by Gill (1950: 253) as being comparable with neither *N. linguifera* nor *N. otophera*. From the little information provided by Gill (1950), it is only possible to differentiate between the Bell Shale specimens and those from the Murrindal Limestone on the basis of their cardinal extremities. The specimens from the Eldon Group possess non-alate cardinal extremities, whereas those of *N. adamantea* are variably alate (Fig. 6A, E, G, I, K). A second unnamed species of *Notoleptaena*, described by Talent (1965b) from the Stoddart Member of the Mount Ida Formation of Victoria, was referred to *N. otophera* by Talent et al. (2001).

Family DOUVILLINIDAE Caster, 1939
Subfamily PROTODOUVILLININAE Harper & Boucot, 1978b

Cymostrophia (Protocymostrophia) Harper & Boucot, 1978b

Type species. By original designation of Caster (1939: 148); *Leptaena stephani* Barrande, 1848; Lochkovian Kotýs Limestone, Svaty Jan pod Skalou, Czech Republic.

Remarks. *Protocymostrophia* was erected by Harper & Boucot (1978b) as a subgenus of *Mesodouvillina* for mesodouvillinids that are moderately to strongly concavo-convex and possess an ornament similar to *Cymostrophia*, features lacking in the other subgenera, *M. (Mesodouviella)* and *M. (Mesodouvillina)*. Whereas Harper & Boucot (1978b) recognised many similarities between *M. (Protocymostrophia)* and *M. (Mesodouvillina)*, they also noted a number of similarities with *Cymostrophia*, including ornament and well-developed braced plates. According to Harper & Boucot (1978b) these commonalities rarely occur in other mesodouvillinids and Rong & Cocks (1994) stated that such characteristics are important for differentiating strophomenid genera. This no doubt led Rong & Cocks (1994) and Cocks & Rong (2000) to reclassify *M. (Protocymostrophia)* as a subgenus of *Cymostrophia*.

According to Cocks & Rong (2000), *C. (Protocymostrophia)* is distinguishable from *C. (Cymostrophia)* by its suboval outline, gently concavo-convex profile and weakly developed interrupted rugae. *Cymostrophia (Cymostrophia)* possesses a more transverse outline, a strongly convex profile and strongly developed interrupted rugae.

Cymostrophia (Protocymostrophia) dickinsi
(Chatterton, 1973)

Fig. 7A-E

Cymostrophia dickinsi sp. nov. Chatterton 1973: 37, pl. 5, figs 31–33; pl. 6, figs 1–9; pl. 7, figs 1–12; pl. 13, figs 1–5.

Cymostrophia multicoستا sp. nov. Chatterton 1973: 42, pl. 6, figs 10–16.

?*Mesodouvillina (Protocymostrophia) cf. dickinsi*-Brock & Talent 1993: 235; fig. 11A, B.

Material. Figured material: AM F117250 (Fig. 7A, B); articulated specimen from McL 417; AM

F117251 (Fig. 7C): ventral valve from ROC 159; AM F117252 (Fig. 7D): ventral valve from ROC 162; AM F117253 (Fig. 7E): dorsal valve fragment from ROC 159. Unfigured material: 42 ventral valves, 17 dorsal valves and 13 articulated specimens.

Description. See Chatterton (1973: 42).

Remarks. Chatterton (1973) assigned two new species, *C. dickinsi* and *C. multicostella*, from the Emsian 'Receptaculites' Limestone Member to *Cymostrophia*, as they agreed the description provided by Caster (1939: 148) for *Cymostrophia*. Chatterton (1973) noted, however, these species differed from Havlíček's (1967: 126) diagnosis for *Cymostrophia* in possessing a convex, rather than a flat, pseudodeltidium, a feature Chatterton (1973) did not regard as generically significant. Harper & Boucot (1978b) subsequently reassigned both species to *Mesodouvillina* (*Protocymostrophia*) as they lacked a notably transverse outline and the trail was not as long as the central disk, an assessment also followed by Brock & Talent (1993). However, as discussed above, both species of Chatterton's (1973) are reassigned to *Cymostrophia* herein.

Brock & Talent (1993) also synonymised *C. (P.) multicostella* with *C. (P.) dickinsi*, although Chatterton (1973) had separated them on slight differences in size, number of costellae, strength of the rugae, position of maximum width of the diductor scars and how much of the hinge line was denticulate. This synonymy appears justified as *C. (P.) multicostella* is merely a smaller version of *C. (P.) dickinsi*.

Cymostrophia (*Protocymostrophia*) *ivanensis* (Barrande, 1879) closely resembles *C. (P.) dickinsi* externally, except that a greater portion of *C. (P.) ivanensis* is covered with rugae (Barrande 1879). The ventral valve muscle field of *C. (P.) ivanensis* tends to be more triangular in outline than that of *C. (P.) dickinsi* and is only divided by a fine myophragn, rather than a grooved median ridge. The dorsal valve muscle field of *C. (P.) dickinsi* is divided by a variably developed median ridge, whereas that of *C. (P.) ivanensis* is crossed by two narrow and slightly anteriorly divergent ridges which have a median septum located between them (Barrande 1879).

Cymostrophia (*Protocymostrophia*) has also been recovered from the Emsian Ukalunda Beds of Queensland (Brock & Talent 1993). Brock & Talent (1993) tentatively referred their material to *C. (P.) dickinsi* due to variation in outline and size of the ventral valve muscle field compared with that described by Chatterton (1973).

Subfamily PROTODOUVILLININAE Harper & Boucot, 1978b

Malurostrophia Campbell & Talent, 1967

Type species. By original designation of Campbell & Talent (1967: 309); *Malurostrophia flabellicauda* Campbell & Talent, 1967; early Emsian *Receptaculites* Limestone Member of the Taemas Limestone, Taemas, New South Wales, Australia.

Malurostrophia sp. cf. *M. flabellicauda* Campbell & Talent, 1967
Fig. 8G-K

cf. *Malurostrophia flabellicauda* sp. nov. Campbell & Talent 1967: 311, pl. 47, figs 1-16; pl. 48, figs 1-20; pl. 49, figs 1-8; pl. 50, figs 8-10.

?*Malurostrophia flabellicauda reverta* subsp. nov. Chatterton 1973: 50, pl. 9, figs 1-10.

cf. *Malurostrophia minima* sp. nov. Chatterton 1973: 52, pl. 10, figs 11-29.

?*Malurostrophia aura* sp. nov. Chatterton 1973: 54, pl. 10, figs 1-10.

?*Malurostrophia bellu* sp. nov. Chatterton 1973: 55, pl. 11, figs 1-17.

Material. Figured material: AM F117259 (Fig. 8G, H): ventral valve from ROC 159; AM F117260 (Fig. 8I, J): articulated specimen from ROC 159. AM F126346 (Fig. 8K): ventral valve from ROC 176.9. Unfigured material: one ventral valve and three articulated specimens.

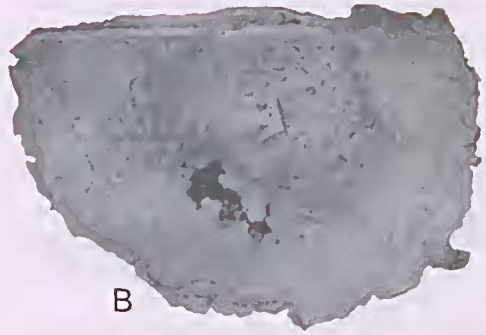
Description. See Chatterton (1973: 52).

Remarks. Chatterton (1973) described three new species of *Malurostrophia*, *M. bella*, *M. aura* and

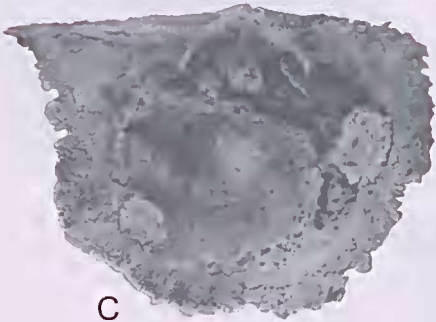
Fig. 7. A-E, *Cymostrophia* (*Protocymostrophia*) *dickinsi* (Chatterton, 1973). A, B, dorsal and ventral views of articulated specimen, McL 417, AM F117250, x 2. C, ventral valve interior, ROC 159, AM F117251, x 2. D, ventral valve interior, ROC 162, AM F117252, x 2. E, cardinal process, ROC 159, AM F117253, x 4. F-I, *Mesoleptostrophia* (*Paraleptostrophia*) *clarkei* (Chatterton, 1973). F, dorsal valve interior, McL 420dh, AM F117254, x 5. G, dorsal view of articulated specimen, ROC 159, AM F117255, x 2. H, ventral valve interior, ROC 159, AM F117256, x 2.



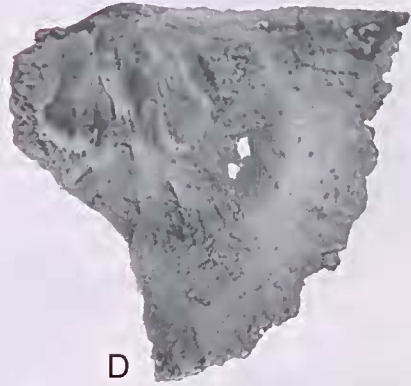
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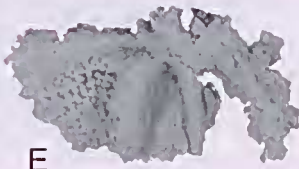
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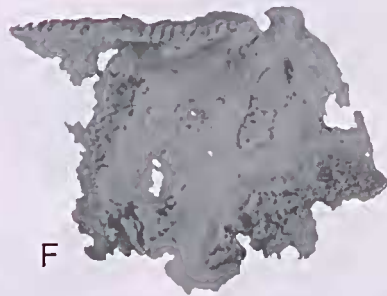
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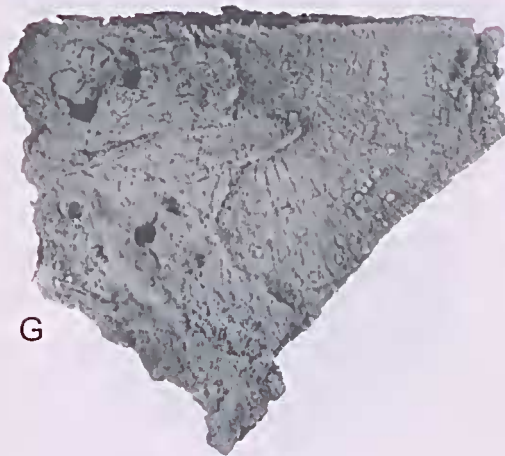
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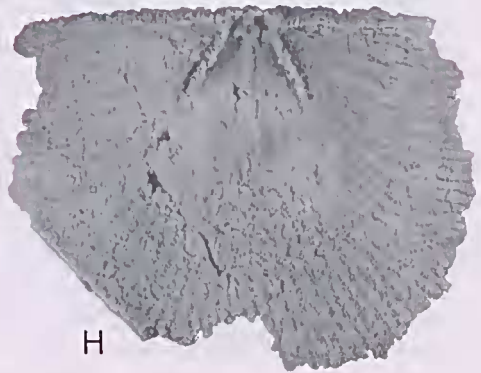
E



F



G



H

M. minima and a new subspecies of *M. flabellicauda*, *M. flabellicauda reverta*, from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas. Chatterton (1973) differentiated these species on size, length from the ventral valve beak to the beginning of the dorsal deflection of the anteriomedian portion of the shell, the degree of alation, the angle formed by the cardinal setal grooves with the hinge line, the presence or absence of a dorsal reversal in the growth of the lateral margins and the height to width and length to width ratios.

Although the specimens recovered from the Murrindal Limestone fall within the range of characteristics provided by Chatterton (1973) for *M. minima*, Talent et al. (2001) considered Chatterton's (1973) *Malurostrophia* species to be junior synonyms of *M. flabellicauda*. Examination of topotype material from Taemas confirms this observation. Indeed, the differences Chatterton (1973) used to distinguish the species are minor and the species appear to intergrade—*M. minima* to *M. flabellicauda* to *M. aura* to *M. flabellicauda reverta* and *M. bella*. In addition, Chatterton (1973) also mentioned the presence of intermediate forms that appear to link *M. minima* with *M. flabellicauda* and *M. flabellicauda* with *M. bella*.

Definite species allocation of the Murrindal specimens, however, is not possible due to previously unobserved morphological variations. The ventral valve muscle field of the Murrindal specimens ranges from 'waisted' (Fig. 8H) to 'non-waisted' (Fig. 8K), with the muscle field of 'waisted' forms being more strongly bilobate than the muscle field of 'non-waisted' forms (Fig. 8H, K). Only one of Campbell & Talent's (1967: pl. 49, fig. 5) specimens shows any 'waisting' of the ventral valve muscle field and this is only very weakly developed. Secondly, not all the Murrindal specimens are alate like those recovered by Chatterton (1973) and Campbell & Talent (1967) (Fig. 8H, J, K). Finally, the Murrindal specimens vary in their degree of resupination — alate forms are not as resupinate as non-alate forms.

The only other Early Devonian occurrence of *Malurostrophia* is *M. basilica* Campbell & Talent, 1967 from the Emsian Taravale Formation at

Buehan, Victoria. This species differs from *M. flabellicauda* in its greater size and in having less strongly developed ornament. Internally, *M. basilica* has more sinuous muscle bounding ridges in the dorsal valve than *M. flabellicauda* and the node at the anterior margin of the dorsal valve adductor scars is more strongly expressed (Campbell & Talent 1967).

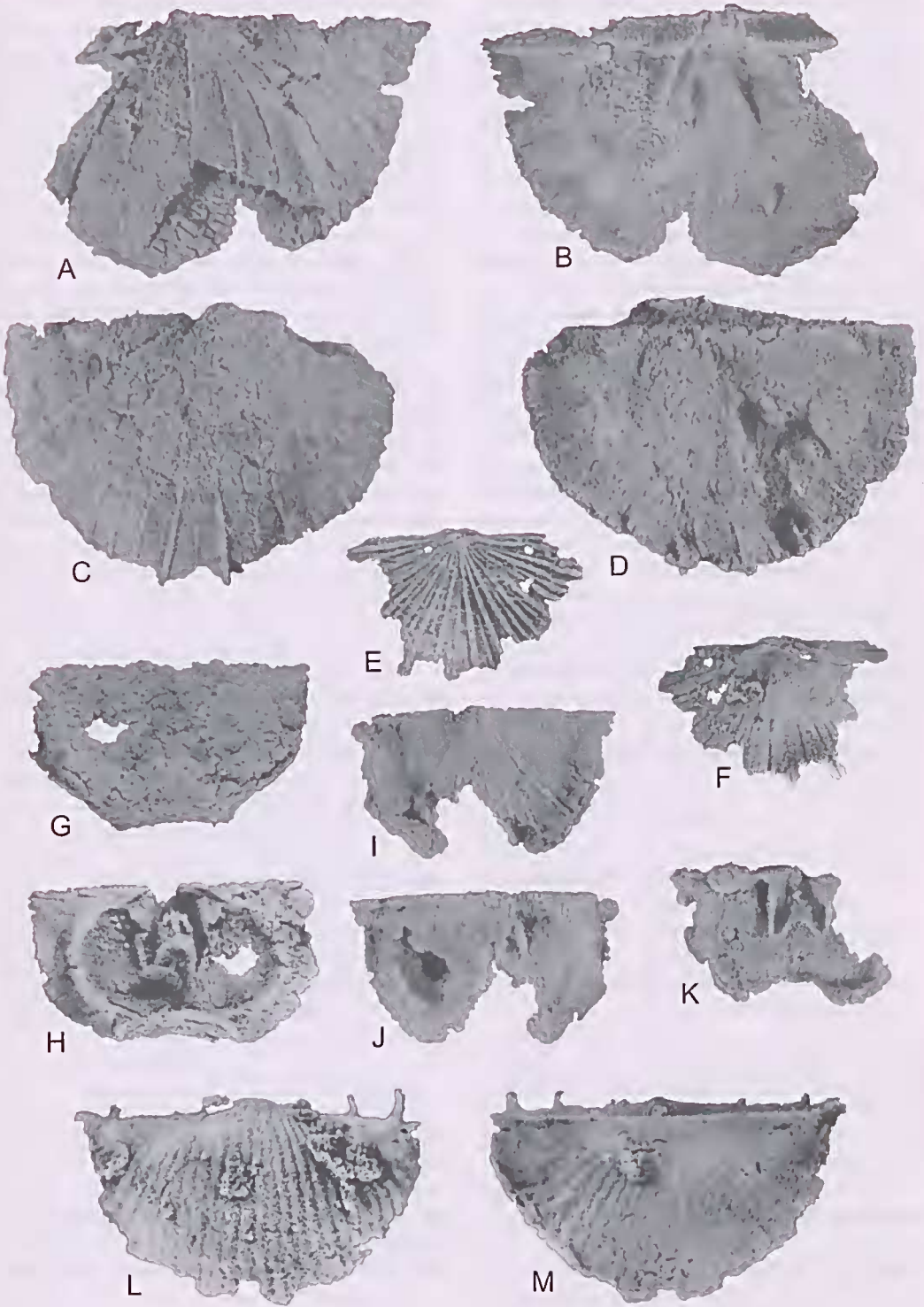
Nadiastrophia Talent, 1963

Type species. By original designation of Talent (1963: 62); *Nadiastrophia superba* Talent, 1963; Pragian Lower Kilgower Member of the Tabberabbera Formation, Victoria, Australia.

Remarks. Brock & Talent (1993) considered *Taemostrophia* Chatterton, 1973 a junior synonym of *Nadiastrophia*, contrary to Chatterton (1973) and Harper & Boucot (1978b), who accepted both genera on the basis that the ventral valve muscle field of *Taemostrophia* differed by being 'waisted'. From their study of specimens from the Emsian Ukalunda Beds and Douglas Creek of Queensland, Brock & Talent (1993) concluded that this feature is highly variable. Parfrey's (1989: pl. 1, figs 4–6) figures of *Taemostrophia* from the same area also show similar variation, whereas the single specimen figured by Hill et al. (1967: pl. D12, fig. 3), only shows slight 'waisting' of the ventral valve muscle field. Close examination of Chatterton's (1973: pl. 8, figs 1–19; pl. 13, figs 6–9) figures also reveals a high degree of variability in this feature. All specimens from the Murrindal Limestone assigned to *Nadiastrophia* lack this feature. Chatterton (1973) and Harper & Boucot (1978b) also suggested that *Taemostrophia* can be differentiated externally from *Nadiastrophia* by having a slightly raised central disk in the ventral valve and by being slightly depressed along the geniculate rim. Talent (1963: 62), however, described *Nadiastrophia* as possessing a slightly raised umbonal region in the ventral valve, which slopes towards the point of geniculation. Therefore, *Taemostrophia* should be considered synonymous with *Nadiastrophia*.

According to Wang (in Wang et al. 1974), the type species of *Xeuostrophia*, *X. yukiangensis*

Fig. 8. A–D, *Nadiastrophia patmorei* (Chatterton, 1973). All specimens x 5. A, B, ventral valve exterior and interior, ROC 159, AM F117257. C, D, ventral and dorsal views of articulated specimen, ROC 159, AM F117258. E, F, *Eoschuchertella murphyi* (Chatterton, 1973), dorsal valve interior and exterior, ROC 165, AM F117261, x 5. G–K, *Malurostrophia* sp. cf. *M. flabellicauda* Campbell & Talent, 1967. All specimens x 5. G, H, ventral valve exterior and interior, ROC 159, AM F117259. I, J, ventral and dorsal views of articulated specimen, ROC 159, AM F117260. K, ventral valve interior, ROC 176.9, AM F126346. L, M, *Johnsonetes australis* (McCoy, 1876), ventral and dorsal views of articulated specimen, ROC 165, AM F117262, x 5.



(Wang, 1956) from the Emsian Yükiang Formation of Kwangsi Province, China, differs from *Nadiastrophia* by being larger, having a less prominent beak, a widely reetangular ventral valve muscle field, shallow pallial markings and having a dorsal valve muscle field which is not elevated on a platform. Harper & Boucot (1978b), however, referred *X. yukiangensis* to *Nadiastrophia*. Examination of the ventral valve muscle field of *X. yukiangensis* shows its outline to be variable. The ventral valve muscle field of the two specimens figured by Wang et al. (1974: pl. 5, figs 4, 5) differs from the ventral muscle field of *N. superba* in being longer, broader and in having the widest point located behind valve midlength. On the other hand, the ventral valve muscle field of the specimen figured by Hou & Zian (1975: pl. 5, fig. 10) is more in keeping with *Nadiastrophia* than *Xenostrophia*, being shorter and thinner, with the widest point at the midlength. Rong & Coeks (1994) believed that generic distinction amongst strophomenoids can only be made on internal features, including the presence or absence of dental or socket plates, muscle bounding ridges, side septa or diaphragms; character states like ornament, dimensions, shell shape and the relative proportion of internal structures can be useful discriminators at the species level. *Xenostrophia* can be questionably considered synonymous with *Nadiastrophia*.

***Nadiastrophia patmorei* (Chatterton, 1973)**

Fig. 8A-D

Nadiastrophia sp. nov. Hill, Playford & Woods 1967: pl. D12, figs 3, 4.

Taenostrophia patmorei sp. nov. Chatterton 1973: 44, pl. 8, figs 1-9; pl. 13, figs 6-9.-Harper & Boucot 1978b: 143, pl. 28, figs 11, 13-16.-Parfrey 1989: pl. 1, figs 1, 2, 4, 7.

Nadiastrophia patmorei-Broek & Talent 1993: 235, fig. 10P-T.

Material. Figured material: AM F117257 (Fig. 8A, B); ventral valve from ROC 159; AM F 117258 (Fig. 8C, D); articulated specimen from ROC 159. Unfigured material: 31 ventral valves and five articulated specimens.

Description. See Chatterton (1973: 44).

Remarks. *Nadiastrophia superba* from the Pragian Lower Kilgower Member of the Tabberabbera Formation, Victoria (Talent 1963), the Pragian Garra Lime-

stone (Lenz & Johnson 1985a) and the Loehkovician Garra Limestone at Eurimbla, New South Wales (Broek 2003a), closely resembles *N. patmorei* from several Emsian localities of eastern Australia (see Hill et al. 1967: d.24; Chatterton 1973: 43; Parfrey 1989: 201; Broek & Talent 1993: 231). They differ, however, in that *N. superba* possesses a more strongly bilobate muscle field in the ventral valve and a greater proportion of the hinge line is denticulate (almost whole length versus half). The dorsal valve of *N. superba* has a laterally directed cardinal process, whereas the lobes are ventrally directed in *N. patmorei* and the socket ridges of *N. superba* diverge at a slightly shallower angle than in *N. patmorei*.

Numerous species of *Nadiastrophia* have been described from Early and Middle Devonian strata of China (see Wang et al. 1987 and Chen et al. 1989 and references therein). They tend to differ from both *N. patmorei* and *N. superba* in possessing less well-developed costellae and are not as strongly transverse or alate. Most also possess a more strongly bilobate ventral valve muscle field than *N. patmorei* and also tend to lack the degree of variation observed by Hill et al. (1967), Chatterton (1973), Parfrey (1989) and Broek & Talent (1993) in the muscle field outline of the ventral valve.

Nadiastrophia insignis Kaplun (in Kaplun & Krupchenko, 1991), from the Lower Devonian Balkhash region of Kazakhstan, is similar to *N. patmorei* externally, although it is not as transverse or alate. However, the ventral valve muscle field of *N. insignis* appears to be variably bilobate, extending for most of the valve length, and lacks evidence of 'waisting'. In addition, the ventral valve muscle field of *N. insignis* is bounded posteriorly and anteriorly by ridges.

Harper et al. (1967: 425) also mentioned the possible occurrence of *Nadiastrophia*, based on a single internal mould of a ventral valve, from the early Emsian Reefton Group of New Zealand. As Harper et al. (1967) did not describe or figure this species, comparisons are not possible.

Family LEPTOSTROPHIIDAE Caster, 1939

Mesoleptostrophia (Paraleptostrophia) Harper & Boucot, 1978a

Type species. By original designation of Harper & Boucot (1978a: 70); *Leptostrophia clarkei* Chatterton, 1973; early Emsian Warroo Limestone Member of the Taemas Limestone, Taemas, New South Wales, Australia.

Remarks. Harper & Boucot (1978a) erected *Mesoleptostrophia* for gently concavo-convex leptostrophiinids with socket plates and a triangular muscle field in the ventral valve bounded laterally by ridges. Harper & Boucot (1978a) also divided *Mesoleptostrophia* into two subgenera, *M.* (*Mesoleptostrophia*), which has divergent socket plates relative to the lateral margins of the cardinal process and *M.* (*Paraleptostrophia*), which possesses socket plates lying parallel to the lateral margins of the cardinal process. Cocks & Rong (2000) separated these genera primarily on the basis of the cardinal process lobes—strongly posteriorly directed in *M.* (*Paraleptostrophia*) and relatively small and ventro-posteriorly directed in *M.* (*Mesoleptostrophia*).

Unlike *M.* (*Mesoleptostrophia*), *M.* (*Paraleptostrophia*) has a relatively restricted distribution, occurring only in Burma (Reed 1908; Anderson et al. 1969; Harper & Boucot 1978a) and Kazakhstan (Kaplan & Krupchenko 1991), in addition to Australia.

Mesoleptostrophia* (*Paraleptostrophia*) *clarkei
(Chatterton, 1973)

Fig. 7F-H

?*Leptostrophia* sp. Whitehouse 1929: 159.

Leptostrophia clarkei sp. nov. Chatterton 1973: 58,
pl. 12, figs 1–13; pl. 13, figs 10–17; pl. 35,
figs 12–14.

Mesoleptostrophia (*Paraleptostrophia*) *clarkei*-Parfrey 1989: pl. 1, figs 7–17, 19–21.-Brock & Talent 1993: 236, fig. 10U, V.

Material. Figured material: AM F117254 (Fig. 7F): dorsal valve from McL 420dh; AM F117255 (Fig. 7G): articulated specimen from ROC 159; AM F117256 (Fig. 7H): ventral valve from ROC 159. Unfigured material: 29 ventral valves, seven dorsal valves and four articulated specimens.

Description. See Chatterton (1973: 58).

Remarks. Harper & Boucot (1978a) reassigned *Leptostrophia clarkei* from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas (Chatterton 1973) and the Emsian Ukalunda Beds and Douglas Creek of Queensland (Whitehouse 1929; Parfrey 1989; Brock & Talent 1993) to *M.* (*Paraleptostrophia*), based on the

socket plates of this species lying subparallel to the lateral margins of the cardinal process lobes. Specimens from the Murrindal Limestone are in general poorly preserved, the dorsal valves in particular, but the socket plates are still observable and lie subparallel to the lateral margins of the cardinal process (Fig. 7F).

In his original description of *M.* (*P.*) *clarkei*, Chatterton (1973) did not mention the bilobed nature of the muscle field in the ventral valve. Although this feature appears to be variable, it is clearly observable in Chatterton's (1973: pl. 12, fig. 1; pl. 13, figs 16, 17) figured material. A variably bilobate ventral valve muscle field also occurs in specimens from the Emsian Ukalunda Beds and Douglas Creek of Queensland (see Parfrey 1989: pl. 1, figs 8, 9, 16 and Brock & Talent 1993: fig. 10U, V). Material from the Murrindal Limestone also displays some degree of bilobation to the ventral valve muscle field (Fig. 7H).

Externally, *M.* (*P.*) *clarkei* is very similar to *M.* (*P.*) *padankpinensis* Anderson, Boucot & Johnson, 1969, from the Eifelian Padaukpin Limestone of Burma, although the ornament of *M.* (*P.*) *clarkei* is slightly coarser. Both valves of *M.* (*P.*) *padankpinensis* possess only short myophores, whereas both valves of *M.* (*P.*) *clarkei* have a median ridge. *Mesoleptostrophia* (*Paraleptostrophia*) *lepsensis* Krupchenko (in Kaplan & Krupchenko, 1991), from the Early Devonian northern Balkhash region of Kazakhstan, has a greater proportion of its hinge line covered with denticles than *M.* (*P.*) *clarkei* (full length versus three-quarters); the muscle scars, though similar in outline, are not as deeply impressed as in *M.* (*P.*) *clarkei*.

Order PRODUCTIDA Sarytcheva & Sokolskaya,
1959

Suborder CHONETIDINA Muir-Wood, 1955

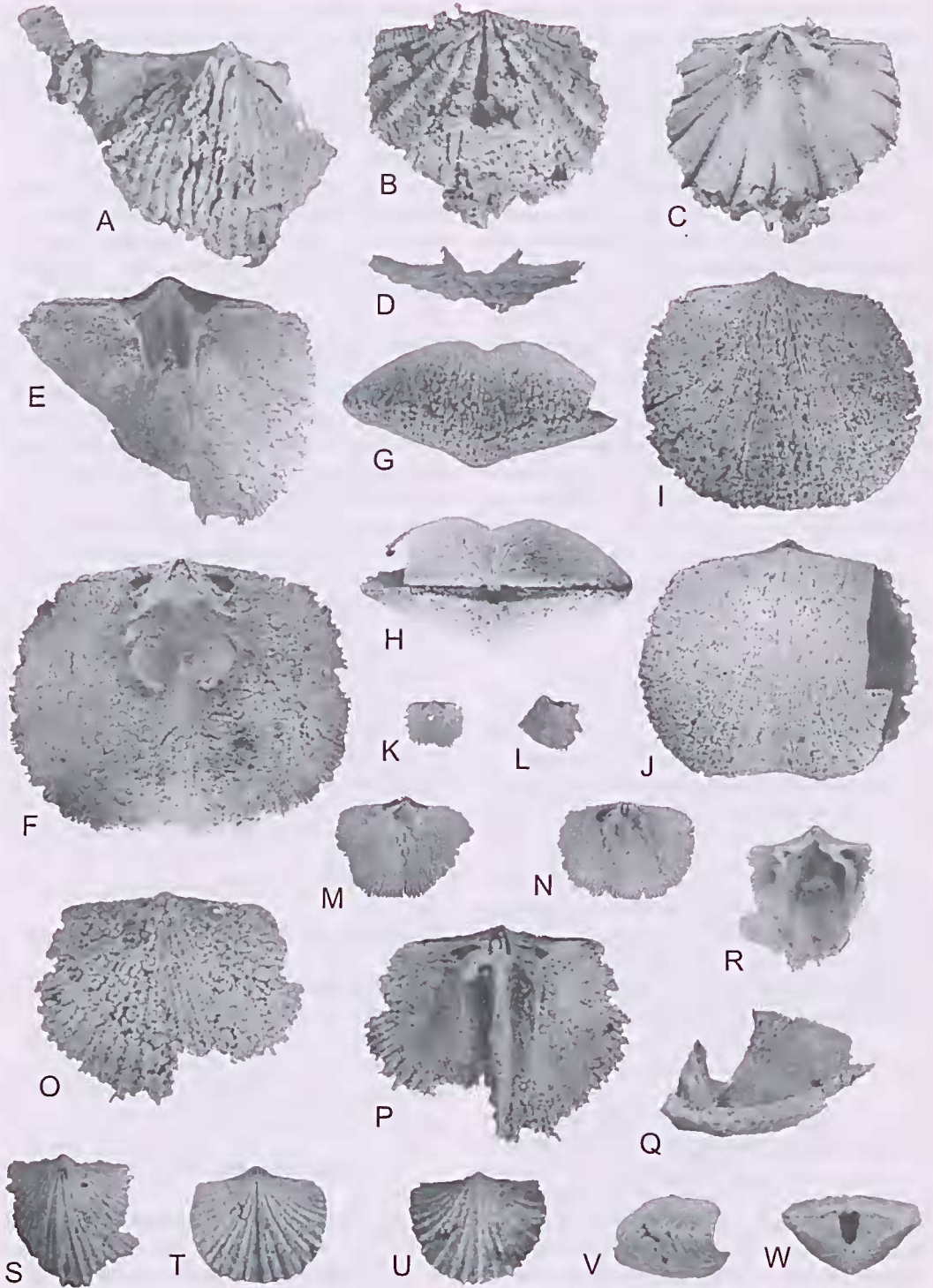
Superfamily CHONETOIDEA Bronn, 1862

Family STROPHOCHONETIDAE Muir-Wood,
1962

Subfamily STROPHOCHONETINAE Muir-Wood,
1962

***Johnsonetes* Racheboeuf, 1987**

Type species. By original designation of Racheboeuf (1987: 7); *Chonetes filistriata* Waleott, 1884; Emsian of Comb's Peak, Eureka District, Nevada, America.



Johnsonetes australis (McCoy, 1876)

Fig. 8L, M

Chonetes australis sp. nov. McCoy 1876: 141, pl. 35, figs 3–5. Gill 1951: 64, pl. 3, figs 18, 19, 21. Talent 1956a: 41, pl. 3, figs 10, 11.

Chonetes teichertii sp. nov. Gill 1951: 70, pl. 3, figs 12–15.

?*Protochonetes* sp. Broek & Talent 1993: 236, fig. 11C–E.

Johnsonetes australis-Strusz 2000: 257, figs 8, 9.

Material. Figured material: AM F117262 (Fig. 8L, M): articulated specimen from ROC 165. Unfigured material: 23 ventral valve fragments and 12 articulated specimens.

Description. See Gill (1951: 64), Talent (1956a: 41) and Strusz (2000: 257).

Remarks. Following Strusz (2000), this species is assigned to *Johnsonetes* as the hinge spines are inserted asymmetrically and spine 1' is absent, the cardinal process is supported by anteriorly divergent, rounded, inner socket ridges and the median costa is enlarged only posteriorly. *Johnsonetes australis* is distinguishable from *J. filistriata* in possessing a greater number of hinge spines and fewer, coarser costae that increase in number occasionally by bifurcation. No trace of the faint undulating concentric striae observed by Waleott (1884) and illustrated by Johnson (1970a: pl. 31, figs 9, 12) in *J. filistriata*, are present in *J. australis*.

Johnsonetes australis is closely related to *J. culleni* (Dun, 1904) from the Emsian 'Spirifer' yassenensis, 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas. Both have a similar size, shape, tendency to develop a weak ventral valve sulcus and a prominent notothyrial platform (Strusz 2000). Dun (1904) confidently separated the two on the basis that *J. culleni* is more strongly convex, possesses fewer and coarser ribs and is less flattened towards the cardinal angles, but Chatterton (1973) regarded *J. culleni* as possibly

being synonymous with *J. australis*. He differentiated them by the anderidia of *J. australis* being located on a pair of low ridges and the socket ridges being more prominent than those of *J. culleni*. Broek & Talent (1993) and Talent et al. (2001) considered *J. culleni* synonymous with *J. australis* and the observed differences a result of intraspecific variation. However, despite rejecting the differences cited by Dun (1904), Strusz (2000) considered *J. australis* and *J. culleni* distinct. In addition to the differences observed by Chatterton (1973), Strusz (2000) stressed the flat ventral valve interarea and the prominent protegular structures of the dorsal and ventral valves in *J. australis* and the weakly concave ventral valve interarea of *J. culleni* and obscure protegular structures of both valves.

Johnsonetes australis is so similar to *J. latus* (Chatterton, 1973) from the Emsian 'Receptaculites' Limestone Member of the Taemas Limestone at Taemas, that Talent et al. (2001) synonymised *J. latus* with *J. australis*. However, Strusz (2000) considered *J. latus* distinct, being small, transverse with distinctly triangular alae and having few hinge spines and deep furrows developed between the ribs. Internally, strongly developed anderidia and the median septum are fused to a prominent notothyrial platform (Strusz 2000).

Johnsonetes australis is also closely related, possibly even synonymous with, an unnamed species referred to *Protochonetes* Muir-Wood, 1962 by Broek & Talent (1993) from the Emsian Ukalunda Beds and Douglas Creek of Queensland. They are similar in size, the development of a sulcus in the ventral valve and internal features of the ventral valve. However, the adductor muscle scars in the ventral valve of *P. australis* tend to be more divergent (Broek & Talent 1993) and the ventral valve median septum to be thicker and shorter. The interior of the dorsal valve and the nature of the hinge spines are not known in the specimens from the Ukalunda Beds and Douglas Creek (Strusz 2000).

Strusz (2000) questionably referred '?*Devonochonetes* sp. 2 of Lenz and Johnson (1985a) from the Pragian Garra Limestone at Wellington to

Fig. 9. A, *Johnsonetes?* sp. cf. *J. culleni* (Dun, 1904), dorsal valve interior, ROC 165, AM F117263, x 5. B–D, *Hesperorthidae* gen. et sp. indet., exterior, interior and posterior views of dorsal valve, ROC 174.1, AM F117264, x 4. E–N, *Tyversella spedenii* Chatterton, 1973. All specimens x 2. E, ventral valve interior, ROC 181, AM F117265. F, dorsal valve interior, ROC 181, AM F117266. G–J anterior, posterior, ventral and dorsal views of articulated specimen, ROC 181, AM F117267. K, dorsal valve interior, ROC 159, AM F126347. L, ventral valve interior, ROC 159, AM F126348. M, ventral valve interior, ROC 159, AM F126349. N, dorsal valve interior, ROC 159, AM F126350. O–W, *Prokopia hillae* (Chatterton, 1973). All specimens x 6. O–Q, exterior, internal and lateral views of dorsal valve, ROC 174.1, AM F117268. R, S, ventral valve interior and exterior, McL 420dh, AM F117269. T–W, dorsal, ventral, lateral and posterior views of articulated specimen, McL 420dh, AM F117270.

Johnsonetes on the presence of a prominent nothoeryal platform, wide cardinal process, a well-developed dorsal valve medium septum and a weakly impressed ventral valve muscle field. It thus closely resembles both *J. australis* and *J. culleni*, but *J. australis* is larger and more coarsely ornamented (Strusz 2000).

Johnsonetes ellesmerensis Racheboeuf, 1987, from the Emsian lower member of the Blue Fiord Formation, Ellesmere Island in the Canadian Arctic Archipelago, is smaller and less strongly concavo-convex than *J. australis*. Internally, *J. ellesmerensis* has a shorter median septum in the dorsal valve and anderidia that are not located on broad ridges. *Johnsonetes arcticus* Racheboeuf, 1987, which occurs higher in the Blue Fiord Formation, may be distinguished from *J. australis* by its larger size, concave ventral interarea and slightly more numerous ribs. Internally, it can be distinguished by teeth which are oval in cross section, a weakly bilobed cardinal process, anderidia that are not located on broad ridges, and by the lack of papillae on the inner surface of the dorsal valve.

Johnsonetes? sp. cf. *J. culleni* (Dun, 1904)

Fig. 9A

?*Chonetes cullei* sp. nov. Dun 1904: 321, pl. 61, figs 1, 1a.

?*Protochonetes culleni*-Chatterton 1973: 69, pl. 16, figs 1–22.

?*Johusouetes culleni*-Strusz 2000: 260, figs 9, 10.

Material. Figured material: AM F117263 (Fig. 9A); dorsal valve from ROC 165.

Description. See Chatterton (1973: 69) and Strusz (2000: 260).

Remarks. The long, posteriorly widened median septum of the dorsal valve, short, wide cardinal process to which anteriorly divergent anderidia are fused, and low rounded socket ridges of this specimen (Fig. 9A) are all reminiscent of *Johusouetes*, particularly *J. australis* and *J. culleni*. The well-developed alae of this specimen suggest that its affinities lie with *J. australis* but, as the anderidia are not raised on ridges, its affinities therefore appear to lie with *J. culleni*. However, as no hinge spines or bases have been preserved in this specimen (Fig. 9A), its assignment to *Johusouetes* must remain doubtful.

Order ORTHOTETIDA Waagen, 1884

Suborder ORTHOTETIDINA Waagen, 1884

Superfamily CHILIDIOPSOIDEA Boucot, 1959

Family AREOSTROPHIIDAE Manankov, 1979

Subfamily ADECTORHYNCHINAE Henry & Gordon, 1985

Eoschuchertella Gratsianova, 1974

Type species. By original designation of Gratsianova (1974: 83); *Eoschuchertella popovi* Gratsianova, 1974; late Emsian Malokorgonsk beds of Gorno-Altai, southwestern Siberia, Russia.

Remarks. *Eoschuchertella* was proposed by Gratsianova (1974) to separate impunctate forms resembling the pseudopunctate *Schuchertella* Girty, 1904. It is upon this basis that the following species has been reassigned to *Eoschuchertella*.

Eoschuchertella murphyi (Chatterton, 1973)

Fig. 8E, F

Schuchertella murphyi sp. nov. Chatterton 1973: 63, pl. 14, figs 1–17.

?*Eoschuchertella* cf. *E. murphyi*-Perry 1979: pl. 1, figs 22–25.-?Perry 1984: 50, pl. 15, figs 13–19.

Material. Figured material: AM F117261 (Fig. 8E, F); dorsal valve from ROC 165. Unfigured material: two ventral valves and four dorsal valves.

Description. See Chatterton (1973: 63).

Remarks. *Eoschuchertella popovi* differs from *E. murphyi* in possessing fine costellae arising by bifurcation in both valves, whereas the costellae of *E. murphyi* are coarser and arise through both bifurcation and intercalation in both valves (Fig. 8F). Internally, *E. popovi* has a more strongly bilobate cardinal process than *E. murphyi* and a less strongly convex pseudodeltidium. The internal surface of *E. murphyi* is strongly and coarsely erenulate, especially around the margins (Fig. 8E), whereas the internal surface of *E. popovi* is more finely and evenly erenulate.

Eoschuchertella murphyi is very similar to *E. hurrenensis* (Savage, 1971) from the Early Devonian Garra Limestone tongue at Manildra (Savage 1971), The Gap (Farrell 1992) and Eurimbla (Brook 2003a), particularly in possessing recurved socket

plates, features of the cardinalia, number and size of costellae, and the lack of dental lamellae (Chatterton 1973). Chatterton (1973) separated them primarily on the maximum size attained by mature individuals, with the largest specimens of *E. murphyi* from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas being less than half the size of some specimens figured by Savage (1971: pl. 73, figs 1-21). Despite only a small number of specimens having been recovered from the Murrindal Limestone, their size (the largest specimen recovered, although incomplete, measures 7 mm in width and 4 mm in length) suggests assignment to *E. murphyi*.

Eoschuchertella is a common component of Early and Middle Devonian strata throughout Canada and Alaska (Chatterton & Perry 1978). Perry (1984) documented three species of *Eoschuchertella* from the Pragian to Emsian sequences of the Delorme Formation, one of which was questionably referred to *E. murphyi*. Perry's (1984) *E. sp. cf. E. murphyi* and the Australian material are identical in terms of ornament, lack of dental lamellae and muscle scars. The Delorme specimens differ though in having only a weakly bilobed cardinal process, a feature regarded as being of taxonomic significance by Williams & Brunton (1993) and Brunton & Cocks (1996).

Another unnamed species of *Eoschuchertella* from the early Pragian Heceta Island of southeastern Alaska was described by Savage (1981) as being identical to *E. burruensis* and to material described by Johnson (1970a) from Nevada and Lenz (1977a) from the Yukon.

Class RHYNCHONELLATA Williams, Carlson,
Brunton, Holmer & Popov, 1996

Order ORTHIDA Schuchert & Cooper, 1932

Suborder ORTHIDINA Schuchert & Cooper, 1932

Superfamily ORTHOIDEA Woodward, 1852

Family HESPERORTHIDAE Schuchert &

Cooper, 1931

Dolerorthis sp.

Fig. 10N-U

Material. Figured material: AM F117276 (Fig. 10N-R); articulated specimen from McL 417; AM F117277 (Fig. 10S, T); ventral valve from ROC 162; AM F117278 (Fig. 10U); dorsal valve from McL 417. Unfigured material: 11 ventral valves, one dorsal valve and four articulated specimens.

Remarks. The ventri-biconvex lateral profile, triangular apsacline ventral valve interarea with an open delthyrium (Fig. 10P, S) and dorsal valve with an anacline interarea and notothyrial platform bearing a blade-like cardinal process (Fig. 10U) indicates affinities with *Dolerorthis* (Schuchert & Cooper 1932; Amsden 1968, 1974; Johnson et al. 1973). However, unlike many other *Dolerorthis*, such as *D. borealis* Lenz, 1977a, from the upper Lochkovian and lower Pragian strata of the Delorme Formation (Lenz 1977a; Perry 1984) and the Lochkovian Garra Limestone at Wellington (Lenz & Johnson 1985a) and Eurimbla (Brock 2003a) and *D. ornata* Lenz & Johnson, 1985a from the Lochkovian Garra Limestone at Wellington, the Murrindal specimens lack third and fourth order costellae (Fig. 10Q, R, T). The first order costellae are well-developed and second order costellae arise at varying distances from the beak through bifurcation and intercalation. The Murrindal specimens differ further in possessing a curved ventral valve interarea cleft by a triangular delthyrium, rather than a slit-like delthyrium with subparallel margins (Fig. 10P, S), by lacking well-developed growth lamellae (Fig. 10Q, R, T) and by their smaller size (ventral valves average 5.33 mm wide and 4.04 mm long; dorsal valves average 5.81 mm wide and 4.06 mm long).

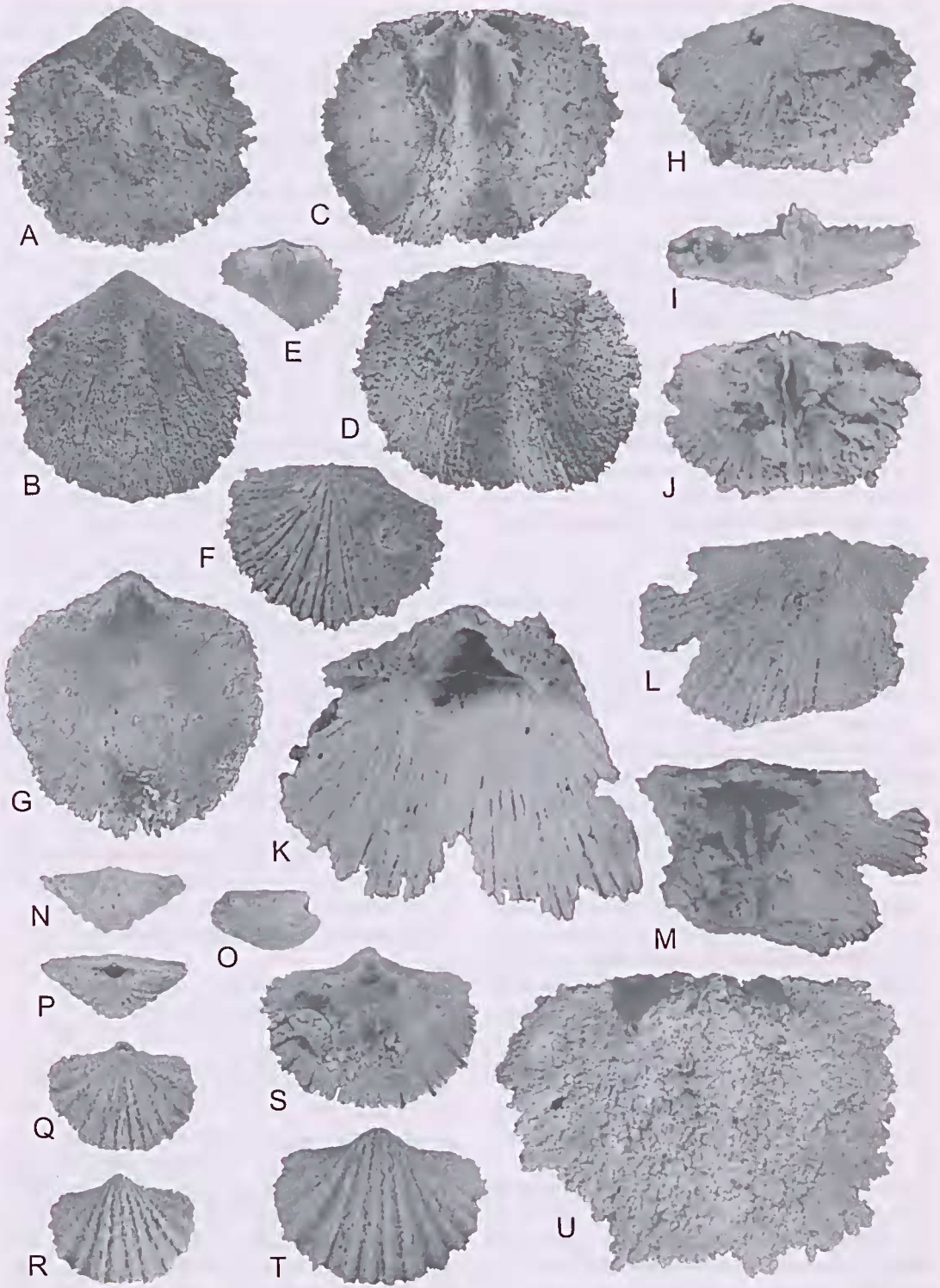
The Murrindal specimens are most similar to *D. persculpta* Philip, 1962 from the latest Lochkovian to earliest Pragian Boola siltstone of the Tyers-Boola area, central Victoria. Both species lack third and fourth order costellae and possess a curved ventral valve interarea cleft by a triangular delthyrium. The Murrindal specimens differ primarily from *D. persculpta* in their slightly smaller size, fewer primary costae and lack of growth lamellae. Additional material, particularly dorsal valves, are required before a more positive identification is possible.

Hesperorthidae gen. et sp. indet.

Fig. 9B-D

Material. Figured material: AM F117264 (Fig. 9B-D); dorsal valve from ROC 174.1.

Remarks. The internal features of this dorsal valve resemble *Dolerorthis* in possessing well-developed, divergent brachiophores, a simple ridge-like cardinal process, a low broad, indistinct median ridge extending to valve midlength and long narrow adductor scars (Fig. 9C). It differs from *Dolerorthis* though in possessing only primary costae (Fig. 9B). The costae of this specimen all arise in the beak



area, whereas the primary costae of *Dolerorthis* arise through bifurcation of and/or intercalation between those originating in the beak area. Zhang (1989) erected *Flabellitesia* for hesperorthids with simple costae, an antygidium and a dorsi-biconvex to resupinate profile. The Murrindal specimen though is flat in profile and lacks an antygidium (Fig. 9D). *Hesperorthis* Schuchert & Cooper, 1931, also possesses simple costae, but differs in possessing an antygidium as well.

This combination of features suggests the Murrindal specimen may represent a new genus of hesperorthid with simple costae and lacking an antygidium. Additional material is required to confirm this.

Suborder DALMANELLIDINA Moore, 1952
Superfamily DALMANELLOIDEA

Schuchert, 1913

Family DALMANELLIDAE Schuchert, 1913

Subfamily ISORTHINAE Schuchert &

Cooper, 1931

Tyersella Philip, 1962

Type species. By original designation of Philip (1962: 197); *Tyersella typica* Philip, 1962; Pragian Coopers Creek Formation, Tyers-Boola area, central Victoria, Australia.

Remarks. Philip (1962) noted that *Tyersella* was likely to be closely related to *Isorthis* due to similarities in ornament, muscle scars, cardinal process and the digitate dorsal pallial sinuses. Talent (1965b: 23) believed *Tyersella* was 'a typical Isorthis' and therefore considered *Tyersella* a subgenus of *Isorthis*. Despite Johnson et al. (1973: 18) claiming *Tyersella* was 'morphologically distinct from *Isorthis*', Walmsey & Boucot (1975) considered *Tyersella* a subgenus of *Isorthis*, based primarily on similarities between the muscle fields of both valves. They distinguished *I. (Tyersella)* from the other subgenera of *Isorthis*, *I. (Isorthis)*, *I. (Protocortezortis)*, *I. (Ovalella)* and *I. (Arcualla)*, on features of the dorsal valve muscle field and the sockets being excavated in the valve floor. Havlíček (1977), Smith

(1980), Kaplun & Krupchenko (1991) and Williams & Harper (2000) have all maintained *Tyersella* as a separate genus, which is followed here. This assessment is based on differences in shell convexity, the presence or absence of fuleral plates and differences in the dorsal valve muscle field.

Tyersella spedeni (Chatterton, 1973)

Fig. 9E-N

Isorthis spedeni sp. nov. Chatterton 1973: 19, pl. 1, figs 8–22; pl. 2, figs 1–14; pl. 5, figs 16–24; pl. 35, fig. 13.

?*Isorthis* sp. Parfrey 1989: pl. 1, fig. 3.

Isorthis (Tyersella) spedeni-Broek & Talent 1993: 233, fig. 91-O.

Material. Figured material: AM F117265 (Fig. 9E): ventral valve from ROC 181; AM F117266 (Fig. 9F): dorsal valve from ROC 181; AM F117267 (Fig. 9G-J): articulated specimen from ROC 181. AM F126347 (Fig. 9K): dorsal valve from ROC 159. AM F126348 (Fig. 9L): ventral valve from ROC 159. AM F126349 (Fig. 9M): ventral valve from ROC 159. AM F126350 (Fig. 9N): dorsal valve from ROC 159. Unfigured material: 238 ventral valves, 257 dorsal valves and 21 articulated specimens.

Description. See Chatterton (1973: 19).

Remarks. *Tyersella typica* is larger than *T. spedeni* and is nonsulcate. The dorsal valve median ridge of *T. typica* extends beyond the anterior margin of the muscle field (Broek & Talent 1993). In addition, *T. spedeni* differs from most other *Tyersella*, such as *T. concinna* (Hall, 1859b) and *T. perelegans* (Hall, 1857), in possessing a well-developed sulcus in the dorsal valve, and having sockets raised on secondary shell material, instead of being excavated in the valve floor.

Ontogeny. Neanic specimens of *T. spedeni* recovered from the Murrindal Limestone are ventribiconvex, with a variably developed shallow sulcus in the dorsal valve. Less than a dozen primary costellae are present with secondary costellae arising through

Fig. 10. A-G, *Resserella careyi* Chatterton, 1973. All specimens x 2. A, B, ventral valve interior and exterior, ROC 162, AM F117271. C, D, dorsal valve interior and exterior, ROC 162, AM F117272. E, ventral valve interior, ROC 159, AM F126351. F, dorsal valve exterior, ROC 159, AM F126352. G, ventral valve interior, ROC 159, AM F126353. H-M, *Biernatium catatum* sp. nov. All specimens x 8. H-J, holotype, exterior, posterior and interior views of dorsal valve, MeL 520, AM F117274. K, ventral valve interior, MeL 520, AM F117273. L, M, dorsal valve exterior and interior, MeL 520, AM F117275. N-U, *Dolerorthis* sp. All specimens x 5. N-R, anterior, lateral, posterior, dorsal and ventral views of articulated specimen, MeL 417, AM F117276. S, T, ventral valve interior and exterior, ROC 162, AM F117277. U, dorsal valve interior, MeL 417, AM F117278.

intercalation and subdivision. The teeth are small, triangular and supported by short and strongly divergent dental plates. The ventral valve muscle field is bilobate, with the diductor sears being separated by a low ridge upon which the adductor sears are located, with no muscle bounding ridges (Fig. 9L). The cardinal process is simple and nonlobed. The brachiophores are strongly divergent and supported by small brachiophore plates that extend forward as low muscle bounding ridges. The midpoint of the muscle bounding ridges is notched, marking the boundary between the posterior and anterior pair of adductor sears that are otherwise indistinguishable. The sockets are variably raised on secondary shell material (Fig. 9K).

Sub-adult *T. spedeni* are subequally biconvex, the dorsal valve becoming more strongly convex compared to neanic specimens. The ventral valve muscle field is more firmly impressed and elongate than in neanic specimens and weakly developed muscle bounding ridges are present laterally (Fig. 9K). The cardinal process has become bilobed and elevated on a notothyrial platform. The dorsal valve median ridge is enlarged and the adductor sears are separated by weakly developed ridges divergent from the median ridge at 90°. The sockets of juvenile specimens are raised on secondary shell material and lack fuleral plates (Fig. 9N).

The same growth patterns observed in sub-adult *T. spedeni* continue into adults. In particular, adult specimens are almost equally biconvex, the ventral valve remaining slightly more strongly convex than the dorsal valve (Fig. 9G, H). Internally, the muscle fields of both valves have become more firmly impressed and the muscle bounding ridges are more strongly developed (Fig. 9E, F). Gerontic specimens appear very similar to adult specimens, but have more deeply impressed muscle sears and more strongly developed muscle-bounding ridges in both valves. The cardinal process of some gerontic specimens is trilobed.

Subfamily PROKOPINAE Wright, 1965

Prokopia Havlíček, 1953

Type species. By original designation of Havlíček (1953: 6); *Prokopia bouskai* Havlíček, 1953;

Pragian Dvorec-Prokop Limestone, Barrandov, Czech Republic.

Prokopia hillae (Chatterton, 1973)

Fig. 9J-R

Muriferella hillae sp. nov. Chatterton 1973: 28, pl. 3, figs 1–9, 11–15; pl. 35, figs 4, 5.

Prokopia hillae-Lenz & Johnson 1985a: 53, pl. 3, figs 1–12.

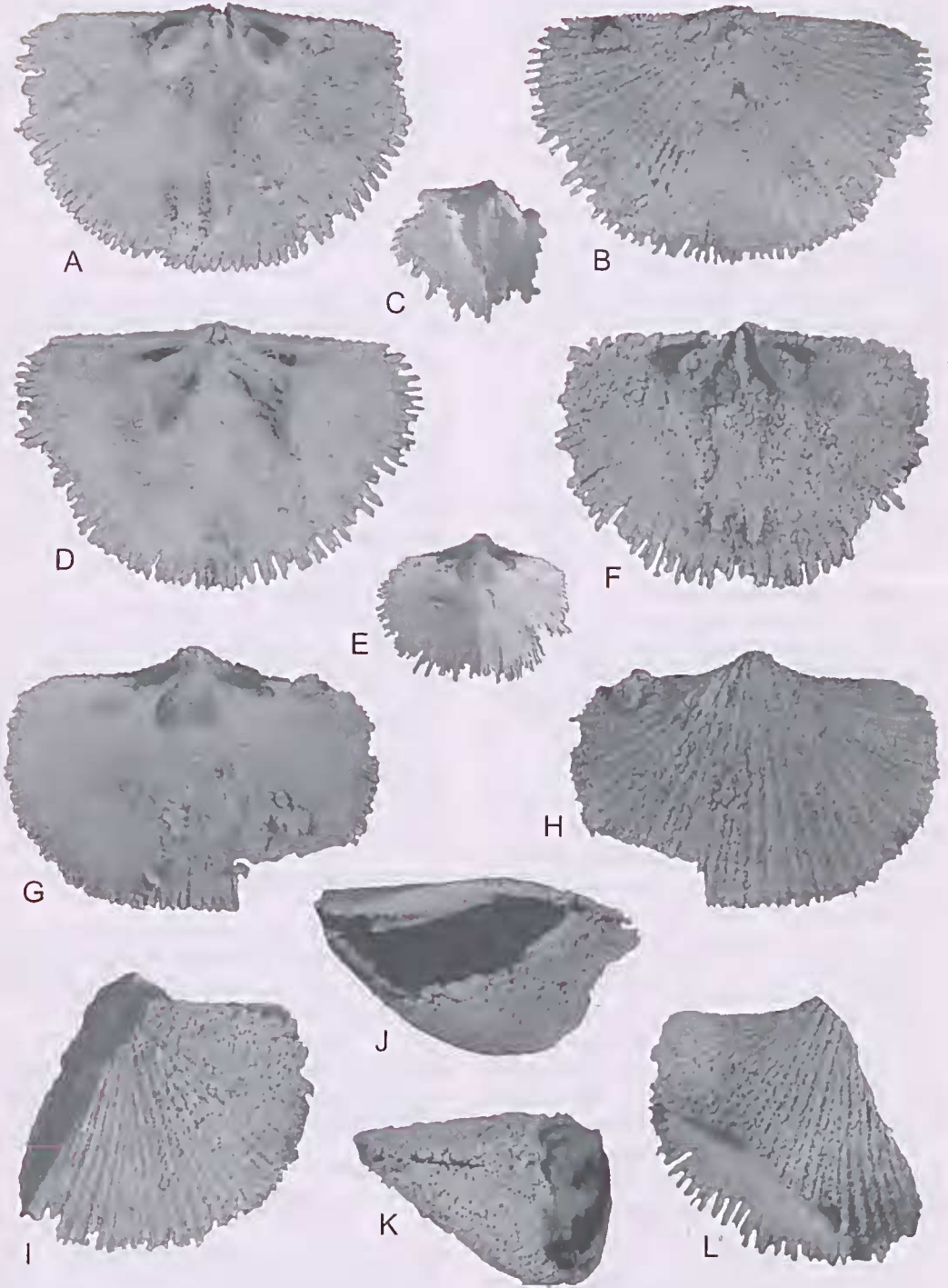
Material. Figured material: AM F117268 (Fig. 9J-L); dorsal valve from ROC 174.1; AM F117269 (Fig. 9M, N); ventral valve from McL 420dh; AM F117270 (Fig. 9O-R); articulated specimen from McL 420dh. Unfigured material: 65 ventral valves, 37 dorsal valves and 12 articulated specimens.

Description. See Chatterton (1973: 28).

Remarks. Following Lenz & Johnson (1985a), *M. hillae* is assigned here to *Prokopia* on the presence of a high triangular median septum in the dorsal valve. Talent et al. (2001), on the other hand, placed this species in synonymy with *M. punctata* (Talent, 1963). However, this synonymy cannot be supported as Johnson & Talent (1967: 44) stated that the median septum of *Muriferella* '...is not high and triangular. All of the specimens investigated show only a slight increase in height of the median septum in the anterior direction.' This statement holds true for all other described species of *Muriferella*.

Some of the specimens assigned to *P. hillae* from the Murrindal Limestone, as well as those described by Chatterton (1973: pl. 3, figs 2, 6, 9) from the Emsian Warroo Limestone Member of the Taemas Limestone at Taemas, differ from Havlíček's (1953) diagnosis for *Prokopia* in possessing fuleral plates (Fig. 9L). Whereas Lenz & Johnson (1985a) made no mention of fuleral plates in their description of *P. hillae* from the Pragian Garra Limestone at Wellington, their figured specimens (pl. 3, figs 1–12) appear to lack them. Although fuleral plates are more characteristic of *M. punctata* than *P. hillae*, they are an unreliable taxonomic feature as their presence varies with the age and size of the individual (Baneroff 1945; Broek pers. comm. 2000).

Fig. 11. *Bidigitus murrindalensis* gen. et sp. nov. All specimens x 8. A, B, holotype, dorsal valve interior and exterior, ROC 159, AM F117279. C, dorsal valve interior, ROC 174.1, AM F126354. D, dorsal valve interior, ROC 159, AM F117280. E, ventral valve interior, McL 420dh, AM F126355. F, dorsal valve interior, ROC 162, AM F117281. G, H, ventral valve interior and exterior, ROC 174.1, AM F117282. I-L, dorsal, lateral, posterior and ventral views of articulated specimen, ROC 162, AM F117283.



Therefore, the presence or absence of fuleral plates in these specimens cannot be considered sufficiently significant to rule out assignment of this species to *Prokopia*.

Subfamily RESSERELLINAE Walmsley &
Boucot, 1971

Resserella Baneroff, 1928

Type species. By original designation of Baneroff (1928: 54); *Orthis canalis* Soverby in Murchison, 1839; Early Silurian, Wenlock Shale, Woolhope Inlier, Herefordshire, Wales.

Resserella careyi Chatterton, 1973
Fig. 10A-G

Resserella careyi sp. nov. Chatterton 1973: 23, pl. 3, figs 10, 16-27.

Curranella careyi gen. et sp. nov. Chatterton 1973: pl. 35, figs 1-3.

Material. Figured material: AM F117271 (Fig. 10A, B) ventral valve from ROC 162; AM F117272 (Fig. 10C, D) dorsal valve from ROC 162; AM F126351 (Fig. 10E): ventral valve from ROC 159; AM F126352 (Fig. 10F): dorsal valve from ROC 159. Unfigured material: 601 ventral valves, 344 dorsal valves and 185 articulated specimens.

Description. See Chatterton (1973: 23).

Remarks. Chatterton (1973: 25) noted that *R. careyi* is unusual amongst *Resserella*, as diagnosed by Walmsley & Boucot (1971: 494), in possessing teeth and sockets that lack crenulations. However, the teeth of *R. springfieldensis* (Foerste, 1917) from the Wenlock Cedarville Dolomite of Ohio, were described by Walmsley & Boucot (1971: 513) as smooth. The ventral valve muscle field of *R. careyi* is largely confined to the delthyrial cavity and is chordate in juvenile to adult specimens (Fig. 10E-G), as seen in other *Resserella* species such as *R. basalis* (Dalman, 1828) and *R. elongata* (Dalman, 1828) (Walmsley & Boucot 1971). The ventral valve muscle field of gerontic specimens of *R. careyi* though is subtriangular to subpentagonal in outline (Fig. 10A). The *vascula media* of *R. careyi*, as illustrated by Chatterton (1973: pl. 3, figs 25, 27), are subparallel in both valves, a feature Walmsley & Boucot (1971) regard as diagnostic of *Resserella*. The primary difference be-

tween *R. careyi* and other *Resserella* is the symmetrical pattern of branching costellae in the medial region of the dorsal valve (Fig. 10D, F). In contrast, *Resserella* typically displays a pattern of asymmetrically bifurcating costellae in the medial region of the dorsal valve (Walmsley & Boucot 1971).

Some of the Murrindal specimens differ from Chatterton's (1973: 23) original description of *R. careyi* in possessing a short, but broad median ridge in the ventral valve located immediately anterior of the muscle field and disappearing by valve midlength (Fig. 10A). *Resserella logansportensis* Walmsley & Boucot, 1971 from the Pridoli Kenneth Limestone of Indiana and *R. triangularis* (Maurer, 1889) from the Emsian of the Rhineland, both possess a median ridge, but it is much thinner in *R. triangularis* and does not increase in height anteriorly as in *R. logansportensis*. The dorsal valve median ridge of *R. careyi* also occasionally extends beyond the anterior margin of the diductor scars, a feature also occurring in *R. springfieldensis*. As these features tend only to occur in larger specimens, it is concluded they are characteristic of gerontic individuals.

Chatterton (1973: pl. 35, figs 1-3) figured several specimens under the name *Curranella careyi* gen. et sp. nov, despite referring to them as paratypes of *R. careyi* in the text. Strusz (1990: 9) determined this taxon is valid under ICZN Articles 13b and 68d, but as Chatterton (1973) obviously changed the generic placement of *C. careyi*, it can be considered a synonym of *R. careyi* (Strusz 1990).

Subfamily BIDIGITINAE subfam. nov.

Diagnosis. A dalmanellid with a dorsal valve median ridge bifurcating anteriorly into two finger-like projections, that may be raised unsupported above valve floor.

Type genus. By original designation herein; *Bidigitus* gen. nov.; Early Emsian of the Murrindal Limestone, Buchan Group, Buchan, Victoria, Australia.

Bidigitus gen. nov.

Type species. By original designation herein; *Bidigitus murrindalensis* sp. nov.; Emsian of the Murrindal Limestone, Buchan Group, Buchan, Victoria, Australia.

Etymology. L., *bi*, two; L., *digitus*, finger, in reference to the two finger-like projections of the bifurcating median ridge in the dorsal valve.

Type locality and horizon. ROC section (sample ROC 159), early Emsian (*perbonus* Zone), Murrindal Limestone, Buchan Group, Buchan, Victoria, Australia.

Diagnosis. As for subfamily by monotypy.

***Bidigitus murrindalensis* sp. nov.**

Fig. 11A-L

Etymology. Named after the Murrindal Limestone from which this species was recovered.

Diagnosis. As for genus by monotypy.

Type material. Holotype: AM F117279 (Fig. 11A, B); holotype, dorsal valve from ROC 159. Figured paratypes: AM F126354 (Fig. 11C); dorsal valve from 174.1; AM F117280 (Fig. 11D); dorsal valve from ROC 159; AM F126355 (Fig. 11E); ventral valve from McL 420dh; AM F117281 (Fig. 11F); dorsal valve from ROC 162; AM F117282 (Fig. 11G, H); ventral valve from ROC 174.1; AM F117283 (Figs 11I-L); articulated specimen from ROC 162. Unfigured paratypes: 81 ventral valves, 33 dorsal valves and two articulated specimens.

Description. Planoconvex, subcircular to transversely suboval in outline. Width and length approximately equal. Greatest width occurring at, or slightly forward of, hinge line. Cardinal extremities rounded. Ventral valve with weak fold, but median portion more strongly convex than lateral slopes. Dorsal valve with weak, anteriorly widening, sulcus. Anterior commissure weakly unisulate. Ornament finely parvicostellate.

Ventral valve interarea triangular, apsaeline and incurved. Delthyrium broadly triangular, enclosing an angle of 90° that may be blocked apically by secondary shell material and laterally by narrow deltidial plates. Dorsal valve interarea low, elongately triangular and anaeline to almost eataeline. Interarea interrupted medially by a triangular notothyrium.

Ventral valve interior with deep delthyrial cavity. Non-erentulate, triangular teeth extend down to valve floor or supported by short, stout dental plates. Small, nonstriate crural fossettes impressed on sides of teeth. Shallow to deep lateral cavities present between teeth or dental plates and valve wall. Muscle

field chordate, largely confined to delthyrial cavity, with gently arcuate anterior margin. Diductor and adductor muscle scars not well differentiated. Diductors appear to extend further forward than, but do not completely enclose, adductors. Adductor scars broader than diductor scars. Muscle field may be elevated slightly relative to valve floor. Inner surface smooth, apart from crenulated margins.

Dorsal valve interior with posteriorly bilobed cardinal process and myophore. Shaft of cardinal process joins narrow, posteriorly grooved, median ridge. Median ridge low, broad, dividing muscle field. Median ridge bifurcating slightly posterior of anterior margin of muscle field into two finger-like projections extending beyond anterior margin of muscle field, and may be raised, unsupported above valve floor. Brachiophores thickened, rod-like and diverge at 85°. Brachiophore plates continue forward as low muscle bounding ridges laterally, fading away anteriorly. Sockets excavated in valve floor and lacking fuleral plates. Muscle field subtriangular, narrowing anteriorly and not obviously divided into posterior and anterior pairs of adductor scars. Inner surface punctate with crenulated margins.

Measurements. Dimensions are shown in Fig. 12. Average ventral valve width 5.59 mm, length 4.32 mm. Average dorsal valve width 8.9 mm, length is 6.2 mm.

Remarks. *Bidigitus* is assigned to the new subfamily, Bidigitinae, within the Dalmanellidae based on its weakly ventribiconvex to planoconvex profile, chordate ventral valve muscle field that is largely

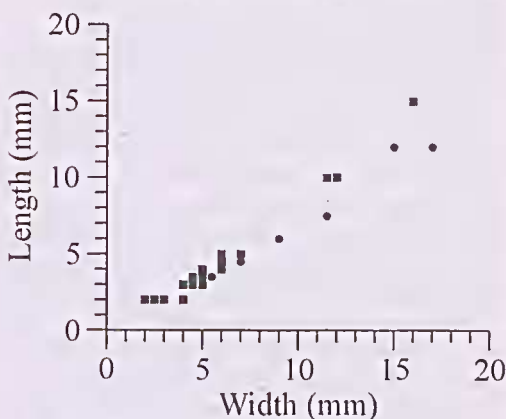


Fig. 12. Dimensions for *Bidigitus murrindalensis* gen. et sp. nov. Length vs width of ■ ventral ($n = 28$) and ● dorsal valves ($n = 10$).

confined to the delthyrial cavity and diductor scars that do not enclose the adductor scars (Fig. 11E). In the dorsal valve simple rod-like brachiophores are supported by brachiophore plates and fulcral plates are absent (Fig. 11A, C). *Bidigitus* is distinguished from all other dalmanellid subfamilies by a dorsal valve median ridge that bifurcates anteriorly into two finger-like projections, that in some specimens stand free of the valve floor (Fig. 111).

The finger-like projections of the median ridge of *B. murrindalensis* probably functioned as accessory lophophore supports to the brachiophores. An analogous structure can be observed in the species of the acrotretid, *Acrotretella*, such as *A. goldapiensis* Biernat & Harper, 1999 and *A. triseptata* Mergl, 2001. In addition to the median septum, these species also possess lateral accessory septa, providing extra support for the lophophore.

Bidigitus murrindalensis has a stratigraphic range extending throughout the ROC section of the Murrindal Limestone, but only occurs in the lower sampled horizons of the McL section (Tables 1, 2). Talent (pers. comm. 2000) however, has indicated that *B. murrindalensis* also occurs in latest Pragian to early Emsian Buchan Caves Limestone.

Ontogeny. Neanic *B. murrindalensis* recovered are all incomplete. The shells are ventri-biconvex with a deep, broad sulcus in the dorsal valve, whereas the ventral valve is evenly convex. The triangular ventral valve interarea is steeply anacline and is flat or slightly curved. The delthyrium is blocked laterally by small deltidial plates, which may or may not join together posteriorly to block the apex of the delthyrium (Fig. 10F). The dorsal valve interarea is flat and anacline. Internally, the ventral valve possesses a deep delthyrial cavity to which the cordate to subtriangular muscle field is largely confined. The teeth are strongly developed, triangular in cross section and fused directly to the valve wall. Some specimens possess faintly impressed crural fossettes. Lateral cavities developed as shallow depressions only (Fig. 10F). The dorsal valve possesses long flattened brachiophores supported by variably developed brachiophore plates that continue forward as faint muscle bounding ridges. The cardinal process occurs as a simple, unlobed ridge, continuous with the broad, low median ridge, which bears a groove extending along its length. The two thin, finger-like bifurcations of the median ridge are raised, unsupported above the valve floor. The muscle-field is subtriangular and not obviously quadripartite. The

triangular sockets, variably raised on secondary shell material, are covered posteriorly by the dorsal valve interarea (Fig. 10C).

Juvenile specimens of *B. murrindalensis* possess features intermediate between those of earlier and later growth stages. An apparent exception to this is the presence of a weakly developed fold, or even a keel, in the ventral valve of some specimens. Such a feature is not seen in other growth stages. In addition, punctae are clearly visible in both valves of juvenile specimens.

Sub-adult to adult specimens of *B. murrindalensis* are planoconvex, the dorsal valve sulcus having become indistinct (Fig. 10J, K). Internally, the muscle fields of both valves are more firmly impressed and the ventral valve muscle field is largely confined to the delthyrial cavity and has an elevated anterior margin. The teeth are strong, robust and supported in some specimens by short, stout dental plates with strongly impressed crural fossettes. Lateral cavities well developed and distinct (Fig. 11G). The dorsal valve muscle field is bounded by thicker ridges and is elevated above the valve floor. The cardinal process is bilobed in all specimens. The brachiophores are thickened and the sockets of all adult specimens are raised on secondary shell material. The groove on the median ridge is indistinct, particularly posteriorly. The bifurcating prongs of the median ridge are fused to the valve floor throughout their length in most specimens (Fig. 11A, D, F).

The only gerontic specimens recovered are two dorsal valves. These are both flat, with only the faintest trace of a sulcus. Internally, these specimens differ most notably from adult specimens in possessing a prominent bilobed to trilobed cardinal process that fills the notothyrium.

Family MYSTROPHORIDAE Schuchert & Cooper, 1931

Biernatium Havlíček, 1975

Type species. By original designation of Havlíček (1975: 234); *Skenidium fallax* Gürich, 1896; Givettian of the Celechovice na Hlane (upper 'red' horizon) of Moravia.

Remarks. Biernat (1959) placed *B. fallax* in synonymy with *Kaysarella lepida* (Schnur, 1853) as she considered the internal features of the dorsal valves identical. This assessment cannot be supported as the cruralium of *B. fallax* is long, narrow and

extends almost to the anterior margin (Havlíček 1977), whereas the eruralium of *Kayersella* Hall & Clarke, 1892 is restricted to the posterior portion of the valve (Biernat 1959). *Mystrophora* Kayser, 1871, unlike *Biernatium*, possesses a median ridge in the ventral valve (Havlíček 1977; Harper 2000). *Planicardinia* Savage, 1968 from the Lochkovian tongue of Garra Limestone at Manildra, in contrast to *Biernatium*, possesses a vertical, spoon-shaped eruralium. Members of the Protorthida possessing a eruralium, like *Skenidioides* Schuchert & Cooper, 1931, differ from *Biernatium* in possessing an open delthyrium, a free spondylium and are impunctate (Williams & Harper 2000).

***Biernatium catastum* sp. nov.**

Fig. 10H-M

Etymology. *L. catasta*, stage, platform, scaffold; in reference to the diamond-shaped eruralium.

Diagnosis. *Biernatium* with an elongate, diamond-shaped eruralium in the dorsal valve.

Type material. Holotype: AM F117274 (Fig. 10H-J): dorsal valve from MeL 520. Figured paratypes: AM F117273 (Fig. 10K): ventral valve from MeL 520; AM F117275 (Fig. 10L, M): dorsal valve from MeL 520. Unfigured paratypes: 12 ventral valves, 18 dorsal valves and one articulated specimen.

Type horizon and locality. MeL section (sample MeL 520), Emsian (*perbomus* Zone), Murrindal Limestone, Buchan Group, Buchan, Victoria, Australia.

Description. Ventribiconvex shells, transversely suboval in outline. Length tending to be slightly greater than width. Cardinal extremities rounded right angles. Maximum width occurring at, or slightly posterior of, midlength. Ventral valve subpyramidal, occasionally with a weakly developed fold. Dorsal valve weakly convex with well-developed sulcus extending from beak to anterior margin, becoming broader and deeper anteriorly. Base of sulcus angular. Anterior commissure unisulcate. Ornament of subangular costae and occasional growth lines.

Ventral valve interarea triangular, steeply apsaeline to almost catacline and slightly curved. Delthyrium triangular, higher than wide, enclosing angle of 70°. Delthyrium restricted apically by

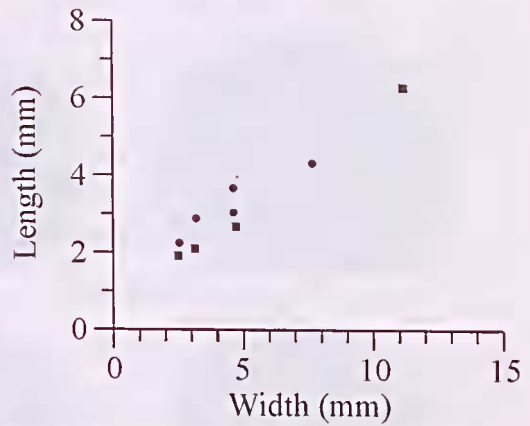
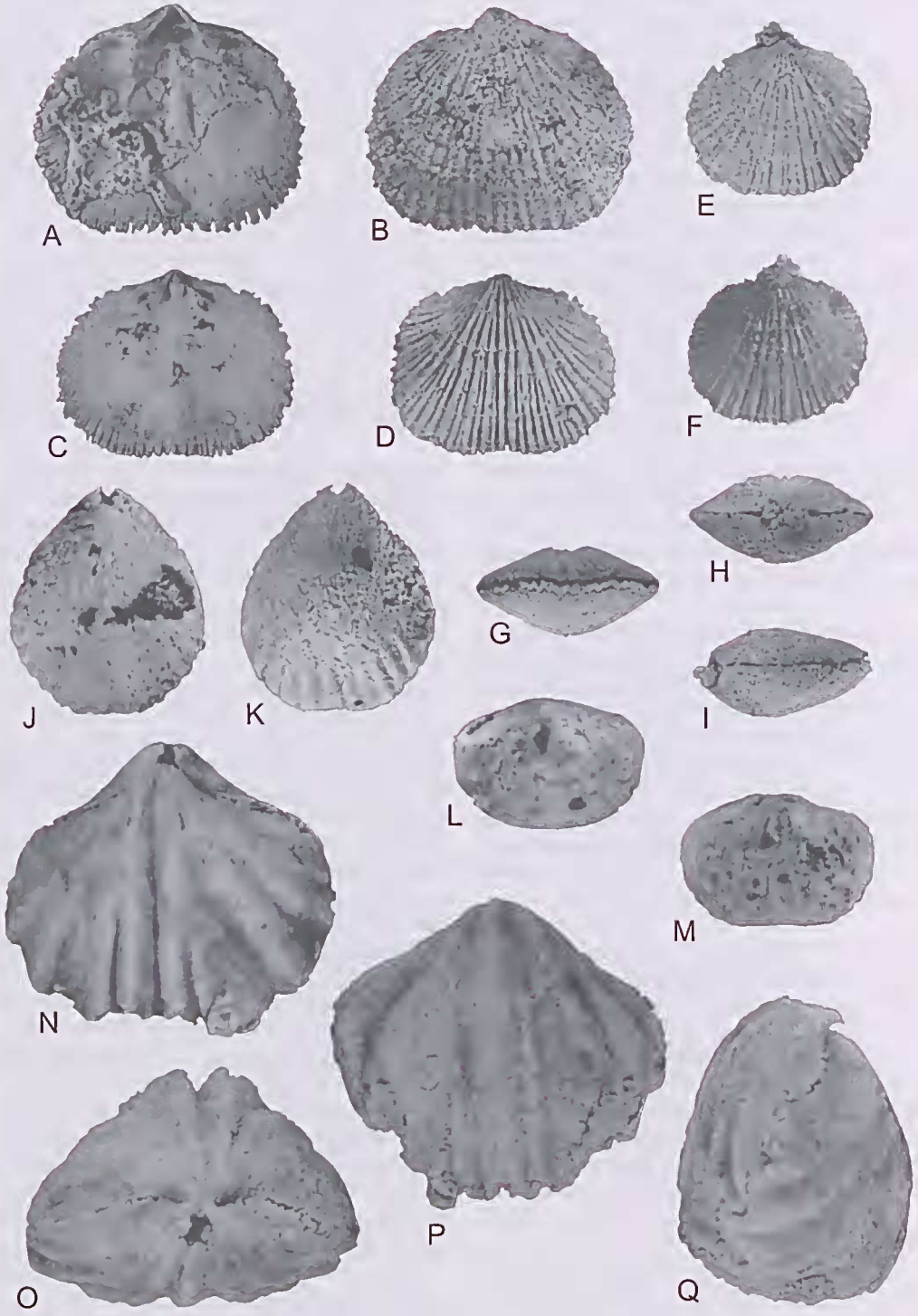


Fig. 13. Dimensions for *Biernatium catastum* sp. nov. Length vs width of ■ ventral ($n = 4$) and ● dorsal valves ($n = 5$).

minute plate and laterally by thin deltidial plates. Dorsal valve interarea triangular, wider than high, steeply anacline and flat. Notothyrium broadly triangular and blocked apically by cardinal process.

Ventral valve interior with deep delthyrial cavity. Teeth flat, triangular and supported by recessive, subparallel dental plates. Muscle field subtriangular and confined largely to posterior half of delthyrial cavity. Anterior margin of muscle field gently arcuate and raised above valve floor. Diductor sears slightly longer than adductor sears, but do not enclose adductors anteriorly. Adductor sears broader than diductors. Inner surface finely erenulate with a suggestion of punctation.

Dorsal valve interior with thickened, ridge-like cardinal process (bilobed in one specimen) with myophore and shaft continuous with median septum. Sockets shallow, raised above valve floor on secondary shell material, lacking fulcral plates. Interarea covers posterior portion of sockets. Median septum thin, triangular in side view, reaching maximum height close to anterior margin and ending at anterior margin. Brachiophores long, triangularly pointed and divergent at 110°. Thin brachiophore plates convergent onto median septum, forming a diamond-shaped eruralium extending at least to valve midlength. Cruralium deeply concave and attached to valve floor posteriorly, rising anteriorly at 30°, becoming shallower as its height increases. Cruralium divided into four fields by median septum and two low, rounded and indistinct ridges, convergent towards cardinal process. Inner surface punctate and marked, at least marginally, by fine crenulations.



Measurements. Dimensions are shown in Fig. 13. Average ventral valve width 5.44 mm, length 3.2 mm. Average dorsal valve width 4.96 mm, length 3.23 mm.

Remarks. *Biernatium catastum* differs from *B. fallax* from the Givetian shales of the Grzegorzowiec-Skaly section of the Holy Cross Mountains of Poland (Havlíček 1977), Givetian of the Celechovice na Hanc (upper 'red' horizon) of Moravia (Fichner & Havlíček 1978) and questionably from the Eifelian of Padaukpin (Northern Shan States), Burma (Havlíček 1975, 1977), primarily on features of the cruralium. The cruralium of *B. fallax* arises from widely divergent brachiophores situated sub-parallel to the hinge line, making the cruralium triangular in shape and much narrower anteriorly than the cruralium of *B. catastum*. The cruralium of *B. fallax* also possesses a weak undulation at its midpoint that, according to Havlíček (1977), resembles the quadripartite condition of the eruralium of *Mystrophora areola* (Quenstedt, 1871). *Biernatium catastum* lacks this feature (Fig. 10H, I, L). In addition, the outline of *B. fallax*, which is semi-oval or semi-circular, differs from the transversely suboval outline of *B. catastum*.

The Murrindal specimens appear most closely related to *B. simplicior* (Barrande, 1879) from the Pragian Koneprusy Limestone of the Czech Republic (Havlíček 1977). Both possess a long cruralium, a high, triangular median septum and a delthyrium blocked laterally by thin deltidial plates and apically by a tiny plate (Fig. 10J). However, according to the diagnosis given by Havlíček (1977: 208), the eruralium of *B. simplicior*, like the eruralium of *B. fallax*, appears to be triangular in shape, suggesting that the brachiophores of *B. simplicior* are more widely divergent than those of *B. catastum*. Direct comparisons, however, are not possible as neither Barrande (1879) nor Havlíček (1977) illustrated the dorsal valve interior of *B. simplicior*.

Kaysarella emanuelensis Veevers, 1959, from the Frasnian of the Fitzroy Basin of Western Australia, is reassigned herein to *Biernatium* following Havlíček (1977), on the basis that the cruralium extends almost to the anterior margin. However, the cruralium of *B. emanuelensis* differs markedly from other members of this genus in remaining narrow

throughout its length and possessing undulating, rather than straight edges. In addition, the median septum of *B. emanuelensis* reaches its highest point around valve midlength, whereas in *B. catastum* this feature occurs closer to the anterior margin (Fig. 10I, L).

Family RHIPIDOMELLIDAE Schuchert, 1913
Subfamily RHIPIDOMELLINAE Schuchert, 1913

Aulacella Schuchert & Cooper, 1931

Type species. By original designation of Schuchert & Cooper (1931: 246); *Orthis eiffliensis* Schnur, 1853; Eifelian of the 'Kalk' of the Eifel, Germany.

Aulacella philipi Chatterton, 1973

Fig. 14A-I

Aulacella philipi sp. nov. Chatterton 1973: 31, pl. 4, figs 13-20; pl. 5, figs 9-15; pl. 35, figs 10, 11.-Broek & Talent 1993: 233, fig. 10A-O.

Aulacella stoermeri sp. nov. Chatterton 1973: 34, pl. 4, figs 1-12; pl. 5, figs 1-8.

Material. Figured material: AM F117284 (Fig. 14A, B): ventral valve from MeL 420dh; AM F117285 (Fig. 14C, D): dorsal valve from MeL 420dh; AM F117286 (Fig. 14E-I): articulated specimen from ROC 165. Unfigured material: 56 ventral valves, 91 dorsal valves and eight articulated specimens.

Description. See Chatterton (1973: 31).

Remarks. Chatterton (1973) described two new species of *Aulacella*, *A. philipi* and *A. stoermeri* from the Emsian 'Receptaulites' and Warroo Limestone Members of the Taemas Limestone at Taemas. He differentiated between them on slight differences in the position of maximum width, length of the hinge line compared to maximum width, degree of flabellation of the diductor scars and the amount of scalloping of the lateral muscle bounding ridges in the muscle field of the ventral valve. However, Chatterton (1973: 34) and Broek & Talent (1993: 233) noted that considerable variation occurs in many features of *A. philipi*. Therefore, these differences

Fig. 14. A-I, *Aulacella philipi* Chatterton, 1973. All specimens x 3. A, B, ventral valve interior and exterior, MeL 420dh, AM F117284. C, D, dorsal valve interior and exterior, MeL 420dh, AM F117285. E-I, dorsal, ventral, anterior, posterior and lateral views of articulated specimen, ROC 165, AM F117286. J-M, *Eoglossinotoechia linki* Chatterton, 1973, ventral, dorsal, posterior and anterior views of articulated specimen, ROC 162, AM F117287, x7. N-Q, 'Pugnax' *oepiki* Chatterton, 1973. N-Q, dorsal, posterior, ventral and lateral views of articulated specimen, MeL 417, AFM117288, x 4.

are considered to fall within the range of intraspecific variation.

Chatterton (1973) and Broek & Talent (1993) believed *A. philipi* to be closely related to the type species, *A. eifliensis* from the Eifelian of Germany and Poland. Chatterton (1973) separated these two species on the basis that *A. philipi* has less rounded costellae and smaller brachiophore plates and teeth. However, given the considerable level of intraspecific variation displayed by *A. philipi*, Chatterton (1973: 34) stated that it was difficult to separate the two species on other characteristics. Broek & Talent (1993) believed these variations may not be significant at the species level and that *A. philipi* could be a junior synonym of *A. eifliensis*. However, comparisons between the two species are difficult due to the considerable level of intraspecific variation displayed.

Order RHYNCHONELLIDA Khun, 1949

Superfamily UNCINULOIDEA Rzhonsnitskaya,

1956

Family GLOSSINOTOECHIIDAE Havlíček, 1992

***Eoglossinotoechia* Havlíček, 1959a**

Type species. By original designation of Havlíček (1959a: 81); *Eoglossinotoechia cacuminata* Havlíček, 1959a; late Loehkavian-Pragian of the Slivence Limestone, Dvorec, Czech Republic.

***Eoglossinotoechia linki* Chatterton, 1973**

Fig. 14J-M

Eoglossinotoechia linki sp. nov. Chatterton 1973: 120, pl. 31, figs 1–22, 27.–Xu 1987: 38, pl. 3, fig. 21.

Material. Figured material: AM F117287 (Fig. 14J-M); articulated specimen from ROC 162. Unfigured material: 14 articulated specimens.

Description. See Chatterton (1973: 120).

Remarks. The specimens assigned to *E. linki* from the Murrindal Limestone closely resemble those recovered by Chatterton (1973) from the Emsian 'Receptaculites' Limestone Member at Taemas. However, as only articulated specimens have been recovered from the Murrindal Limestone, a comparison of internal features is not possible. The Murrindal specimens differ most notably though from those described by Chatterton (1973) in being

smaller (Fig. 15), but only four of the specimens recovered were complete enough to obtain accurate dimensions. The Murrindal specimens also possess less pronounced costae, most likely related to their smaller size.

Eoglossinotoechia linki has also documented by Xu (1987) from the Pragian Daredong Formation of China. The single specimen figured by Xu (1987: pl. 3, fig. 21) has 21 plications developed along the anterior and lateral margins, and falls within the range of 20 to 28 plications established by Chatterton (1973) for mature specimens of *E. linki*. Like *E. linki* from the 'Receptaculites' Limestone Member, those from the Daredong Formation are larger than the Murrindal specimens (Fig. 15).

Eoglossinotoechia linki differs from *E. cacuminata* from the Silurian and Lower Devonian of the Czech Republic (Havlíček 1959a), in possessing fewer and more prominent costae, a less convex ventral valve and a more obviously bilobate cardinal process. Other *Eoglossinotoechia* from the same area, such as *E. mystica* Havlíček, 1959a and *E. sylphidea* (Barrande, 1847), possess fewer and less well-developed costae than *E. linki*. None of the Devonian species of *Eoglossinotoechia* reported

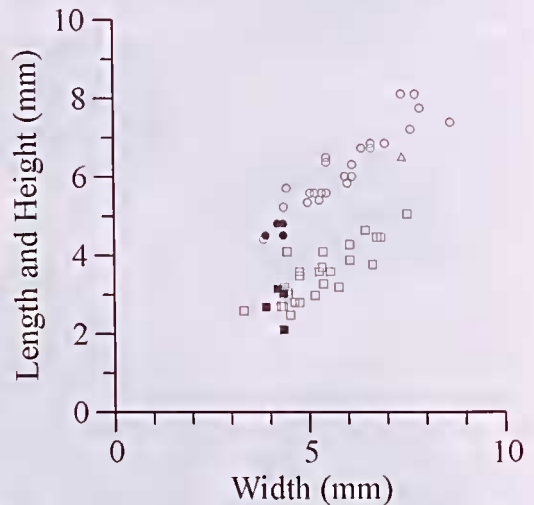


Fig. 15. Comparison of *Eoglossinotoechia linki* from the Emsian 'Receptaculites' Limestone Member at Taemas (average width 16.7 mm; length 6.33 mm; height 4.07 mm) (Chatterton 1973: fig. 40), with *E. linki* from the Murrindal Limestone (average width 4.2 mm; length 4.65 mm; height 2.81 mm) and *E. linki* from the Pragian Daredong Formation of China (Xu 1987: pl. 3, fig. 21). Length vs width of ● Murrindal ($n = 4$), ○ Taemas ($n = 24$) and △ Daredong specimens ($n = 1$). Height vs width of ■ Murrindal ($n = 4$) and □ Taemas specimens ($n = 27$).

from Morocco by Drot (1964) appears closely related to *E. linki* (Chatterton 1973).

Chatterton's (1973) report of *E. linki* from Tasmania was the first recorded occurrence of this genus in Australia. Since then, only one additional species of *Eoglossinotoechia* has been reported from Australia, *E. catombalensis* Lenz & Johnson, 1985b from the Pragian Garra Limestone at Wellington (Lenz & Johnson 1985b) and the Lochkovian Garra Limestone at Eurimbla (Brock 2003b) possesses fewer (12 to 18) and more rounded costae that are developed over the entire shell. The costae of *E. linki*, on the other hand, are flatter, more numerous (20 to 28) and only developed marginally. The ventral valve muscle field of *E. catombalensis* is subtriangular in outline, weakly impressed and divided by a prominent median ridge, whereas the ventral valve muscle field of *E. linki* is more variable in outline, strongly impressed and is not divided by a median ridge. In addition, the dorsal valve of *E. linki* contains a septalium, which is not developed in *E. catombalensis*.

Superfamily PUGNACOIDEA Rzhonsnitskaya,
1956

Family PUGNACIDAE Rzhonsnitskaya, 1956

***Pugnax* Hall & Clarke, 1893**

Type species. By subsequent designation of ICZN Opinion 420 (1956: 134); *Terebratula acuminata* Sowerby, 1822; Visnean subzone D2, Dernyshire, Thorpe Cloud, England.

'*Pugnax*' *oepiki* Chatterton, 1973
Figs 14N-Q, 16A-I

'*Pugnax*' *oepiki* Chatterton 1973: 123, pl. 32,
figs 25-41.

Material. Figured material: AM F117288 (Figs 14N-Q; 16I): articulated specimen from MeL 417; AM F117289 (Fig. 16A): articulated specimen from ROC 162; AM F117290 (Fig. 16B): articulated specimen from ROC 162; AM F117291 (Fig. 16C): articulated specimen from ROC 162; AM F117292 (Fig. 16D): articulated specimen from ROC 162; AM F117293 (Fig. 16E): articulated specimen from ROC 162; AM F117294 (Fig. 16F): articulated specimen from ROC 162; AM F117295 (Fig. 16G): articulated specimen from ROC 162; AM F117296 (Fig. 16H): articulated specimen from ROC 165; AM F117288 (Fig. 16I): articulated specimen from MeL 417. Unfigured mate-

rial: 11 ventral valve fragments, two dorsal valve fragments and 36 articulated specimens.

Description. See Chatterton (1973: 123).

Remarks. Chatterton (1973) questionably assigned this species to *Pugnax* on the basis of a few dorsal valve interiors showing that the erural bases are extended dorsally, fused with the valve floor, and do not converge towards a median septum to form a septalium. Chatterton (1973: 125) also noted this species possesses similarities with *Parapugnax*, such as a well-defined fold and sulcus and a ventral valve that is not flat or concave posteriorly. In addition, this species differs from most other pugnacids, including the type species, in possessing a thin, posteriorly perforated hinge plate that unites the erural bases (Chatterton 1973). This suite of characteristics led Talent et al. (2001) to propose that '*P. oepiki*' may represent a new genus of Pugnacidae, but additional dorsal valve interiors are required before a more positive generic identification is possible. None of the specimens recovered from the Murrindal Limestone show any internal structures.

Order SPIRIFERIDA Waagen, 1883

Remarks. The higher level classification used for the Spiriferida herein follows that of Carter et al. (1994).

Suborder SPIRIFERACEA Waagen, 1883
Superfamily CYRTIOIDEA Frederiks, 1924
Family SPINELLIDAE Johnson, 1970
Subfamily SPINELLINAE Johnson, 1970

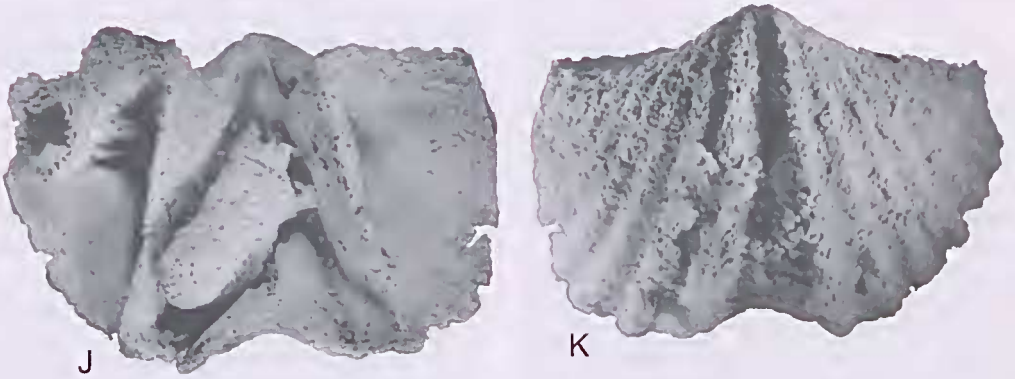
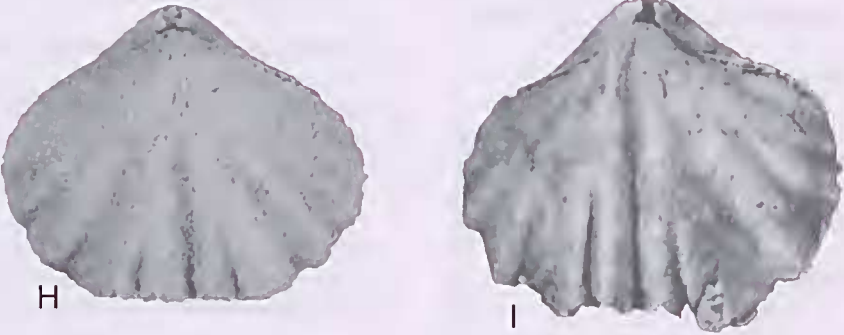
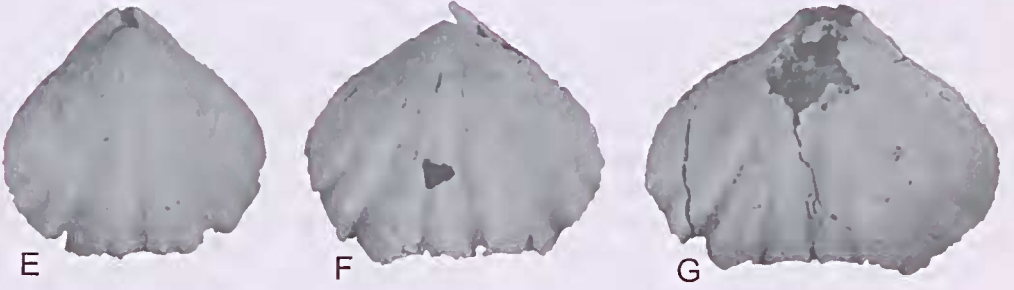
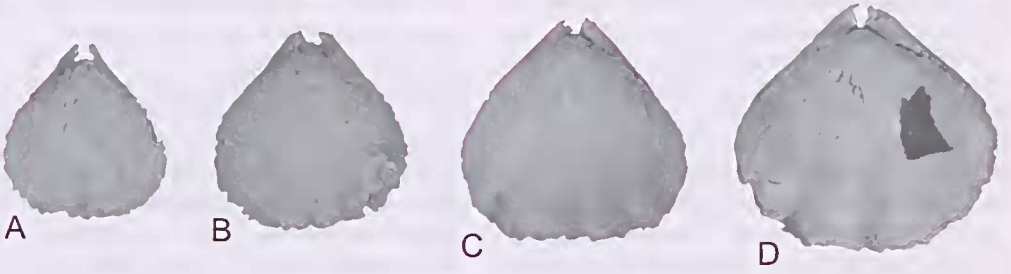
***Spinella* Talent, 1956a**

Type species. By original designation of Talent (1956a: 21); *Spinella buchanensis buchanensis* Talent, 1956a; latest Pragian to early Emsian Buchan Caves Limestone, Buchan Group, Buchan, Victoria, Australia.

***Spinella buchanensis buchanensis* Talent, 1956a**
Figs 16J, K, 17A, B

Spirifera laevicostata-McCoy 1876: pl. 35, figs 2-2b.
Spirifer yassensis-Chapman 1905: 16, pl. 5, figs 2, 3.-
?Chapman 1914: 161, fig. 86E.

Spinella buchanensis sp. nov. Talent 1956a: 22, pl. 1,
figs 1-5; pl. 2, figs 5-7.



?*Spinella*? sp. aff. *S. buchanensis*-Talent 1963: 85, pl. 53, figs 7-9.

Material. Figured material: AM F117297 (Fig. 16J, K): ventral valve from ROC 162; AM F117298 (Fig. 17A, B): dorsal valve from ROC 159. Unfigured material: 24 ventral valves, three dorsal valves and one articulated specimen.

Description. See Talent (1956a: 22).

Remarks. Talent (1956a) divided *S. buchanensis* into three new subspecies, *S. b. buchanensis*, *S. b. scissura* and *S. b. philipi* that differ primarily in the number of plications and in the arrangement of spine bases. The Murrindal specimens are conspecific with *S. b. buchanensis*, possessing lateral slopes with 11 to 14 simple plications. No spine bases were observed. In comparison, *S. b. philipi* is more obese, has lateral slopes bearing 13 to 18 simple plications and has a more strongly incurved ventral valve beak. *Spinella buchanensis scissura* is distinguished by lateral slopes with only 10 to 11 plications and by the plications flanking the sinus bearing a median groove (Talent 1956a). In addition, *S. b. buchanensis* is present not only throughout the Buchan Caves Limestone, but also extends up into the overlying Taravale Formation. The other two subspecies have relatively restricted stratigraphic ranges, being confined to the uppermost parts of the Buchan Caves Limestone (Talent 1956a).

Spinella maga Talent, 1956a, also from the Buchan Caves Limestone, possesses a greater number of plications (lateral slopes bear 18 to 20 plications), a more strongly incurved ventral valve beak and a granular surface ornament compared to *S. b. buchanensis*. *Spinella yassensis* (de Koninek, 1876), from Taemas (Chatterton 1973) and the Emsian Liek Hole Formation at Ravine (Strusz et al. 1970), is distinguishable by its smaller size, more elongate shell, higher fold, greater number of plications and a microornament of more elongate spine bases. *Spinella pittmani* (Dun, 1904), from the Emsian Gleninga Formation of the Yarra Yarra Creek Group and the late Pragian to early Emsian Trofŕs Formation (Dun 1904; Sherwin 1995; Földvary 2000), is similar in size to *S. b. buchanensis*. However, *S. b. buchanensis* is more transverse and has a more rounded sulcus (Sherwin 1995).

Spinella talenti Johnson, 1970a, from the Lower Devonian of Lone Mountain, Nevada, differs primarily in possessing a microornament of radial striae and tends to have flatter plications, but, as noted by both Talent (1956a: 27) and Johnson (1970a: 205), some specimens of *S. b. buchanensis* also have relatively flat plications. Perry (1984) questionably referred a dorsal valve fragment from the Pragian beds of the Delorme Formation to *Spinella*, which he described as being internally very similar to *S. talenti*.

Spinella ineerta (Fuchs in Priestersbaeck & Fuehs, 1909), described by Vandereammen (1963) from the early Emsian of Belgium, appears markedly different from *S. b. buchanensis*. It possesses more numerous and finer plications and a sulcus lacking any costae. The microornament of *S. ineerta* also differs in consisting of subcylindrical spine bases.

Spinella yassensis (de Koninek, 1876)

Fig. 17C-G

Spirifer yassensis de Koninek 1876: 104, pl. 3, fig. 6-6b.-de Koninek 1898: 83, pl. 3, fig. 6-6b.-Sussmilch 1914: fig. 23, 6-6b.-Sussmilch 1922: fig. 23, 6-6b.

Spirifer latisinuatus de Koninek 1876: 105, pl. 3, fig. 7-7b.-de Koninek 1898: 84, pl. 3, fig. 7-7b.

Spinella yassensis yassensis-Strusz, Chatterton & Flood 1970: 176, pl. 7, figs 1-14; pl. 8, figs 1-3, 7, 9-10; pl. 9, fig. 16.

Spinella yassensis ravinia n. subsp. Flood (in Strusz, Chatterton & Flood 1970): 179, pl. 9, figs 1-14, 17.

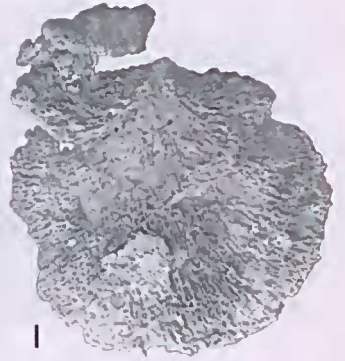
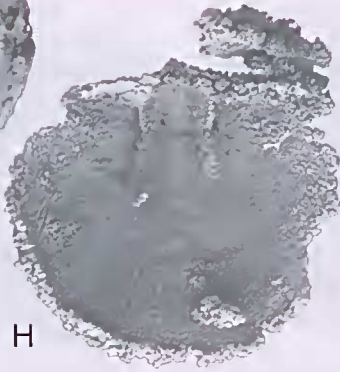
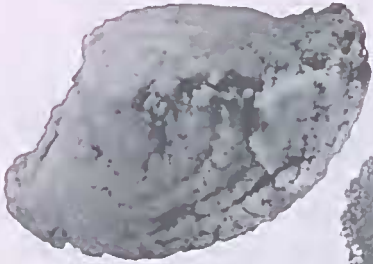
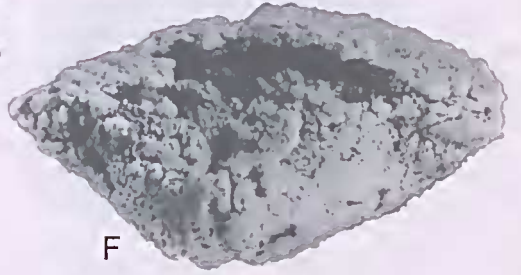
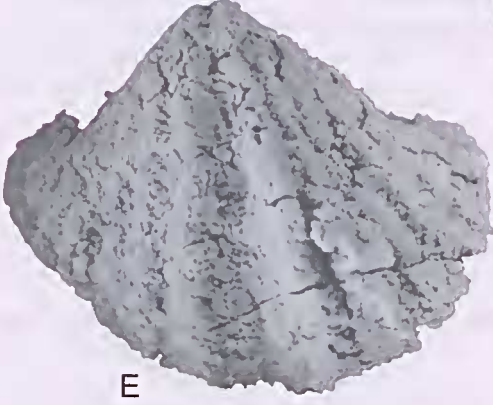
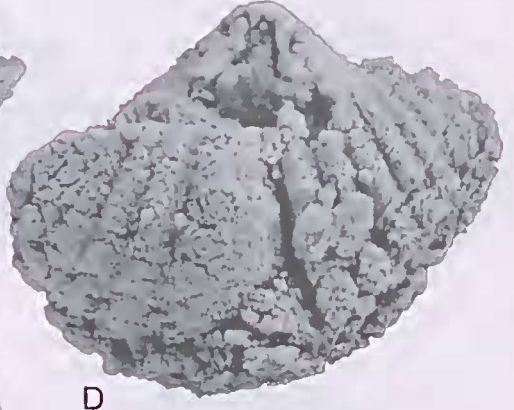
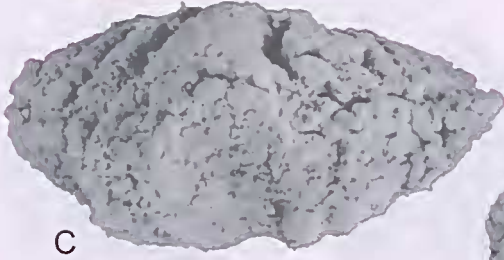
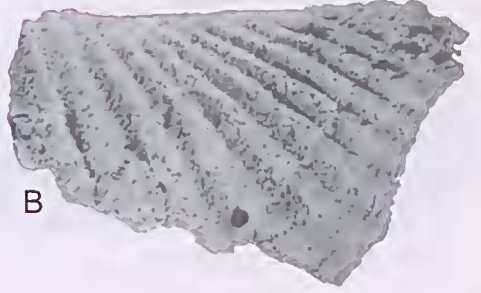
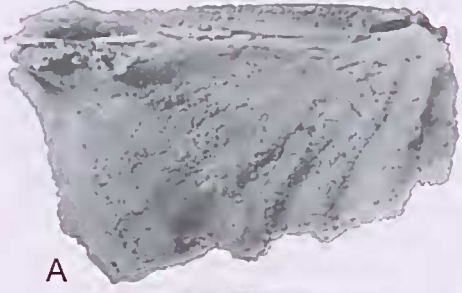
Spinella yassensis, n. subsp? Strusz, Chatterton & Flood 1970: 181, pl. 8, figs 4-6, 8.

Spinella yassensis-Chatterton 1973: 105, pl. 26, figs 1-13; pl. 30, figs 16-20.

Material. Figured material: AM F117299 (Fig. 17C-G): articulated specimen from ROC 165. Unfigured material: one ventral valve.

Remarks. Flood (in Strusz et al. 1970) erected the new subspecies, *S. y. ravinia*, which was defined as having a significantly shallower shell with a narrower and flatter fold and a slightly higher number of plications than *S. y. yassensis*. Following Talent et

Fig. 16. A-I, '*Pugnax*' *oepiki* Chatterton, 1973. All specimens x 4. All dorsal views of articulated specimens. A-G, ROC 162, AM F117289-117295. H, ROC 165, AM F117296. I, McL 417, AM F117288. J, K, *Spinella buchanensis buchanensis* Talent, 1956a, ventral valve interior and exterior, ROC 162, AM F117297, x 3.



al. (2001), however, these differences are not considered great enough to warrant their separation from *S. y. yassensis*.

Strusz et al. (1970) also documented *Spinella yassensis* n. subsp? from the base of the Emsian 'Receptaculites' Limestone Member at Taemas. It was described as being slightly larger, having a greater variability in shape and the curvature of the ventral valve interarea being less pronounced than *S. y. yassensis*. Statistical comparisons showed significant differences between *S. yassensis* n. subsp? and *S. y. yassensis* in terms of shape and relative width of the fold. However, as pointed out by Strusz et al. (1970: 181), only a handful of specimens were available for study and therefore any differences must be considered inconclusive. Until additional material is obtained designation of the Taemas form of *S. yassensis* as a new subspecies appears unwarranted.

Spinella yassensis differs from *S. buchaneensis* in being smaller, more elongate, possessing a higher fold, a greater number of plications in some larger specimens and a microornament consisting of more elongate spine bases. *Spinella maga* possesses significantly more plications and growth lamellae that are only occasionally developed. *Spinella yassensis* appears very similar to *S. pittmani*, but is smaller and some have a ventral valve muscle field that is radially, rather than longitudinally, striate (Sherwin 1995).

Superfamily AMBOCOELIOIDEA George, 1931
Family AMBOCOELIIDAE George, 1931
Subfamily RHYNCHOSPIRIFERINAE
Paulus, 1957

Ambocoelia Hall, 1860

Type species. By original designation of Hall (1860: 71); *Orthis umbonata* Conrad, 1842; Middle Devonian Hamilton Group, New York, America.

Ambocoelia sp. aff. *A. runnegari*
(Chatterton, 1973)
Figs 17H, I, 18A-C

aff. *Ambothyris runnegari* sp. nov. Chatterton 1973:
99, pl. 19, figs 1-14.

Material. Figured material: AM F117300 (Fig. 17H, I): dorsal valve from MeL 520; AM F117301 (Fig. 18A, B): ventral valve from MeL 520; AM F117302 (Fig 18C): articulated specimen from MeL 520. Unfigured material: 15 ventral valves, 12 dorsal valves and three articulated specimens.

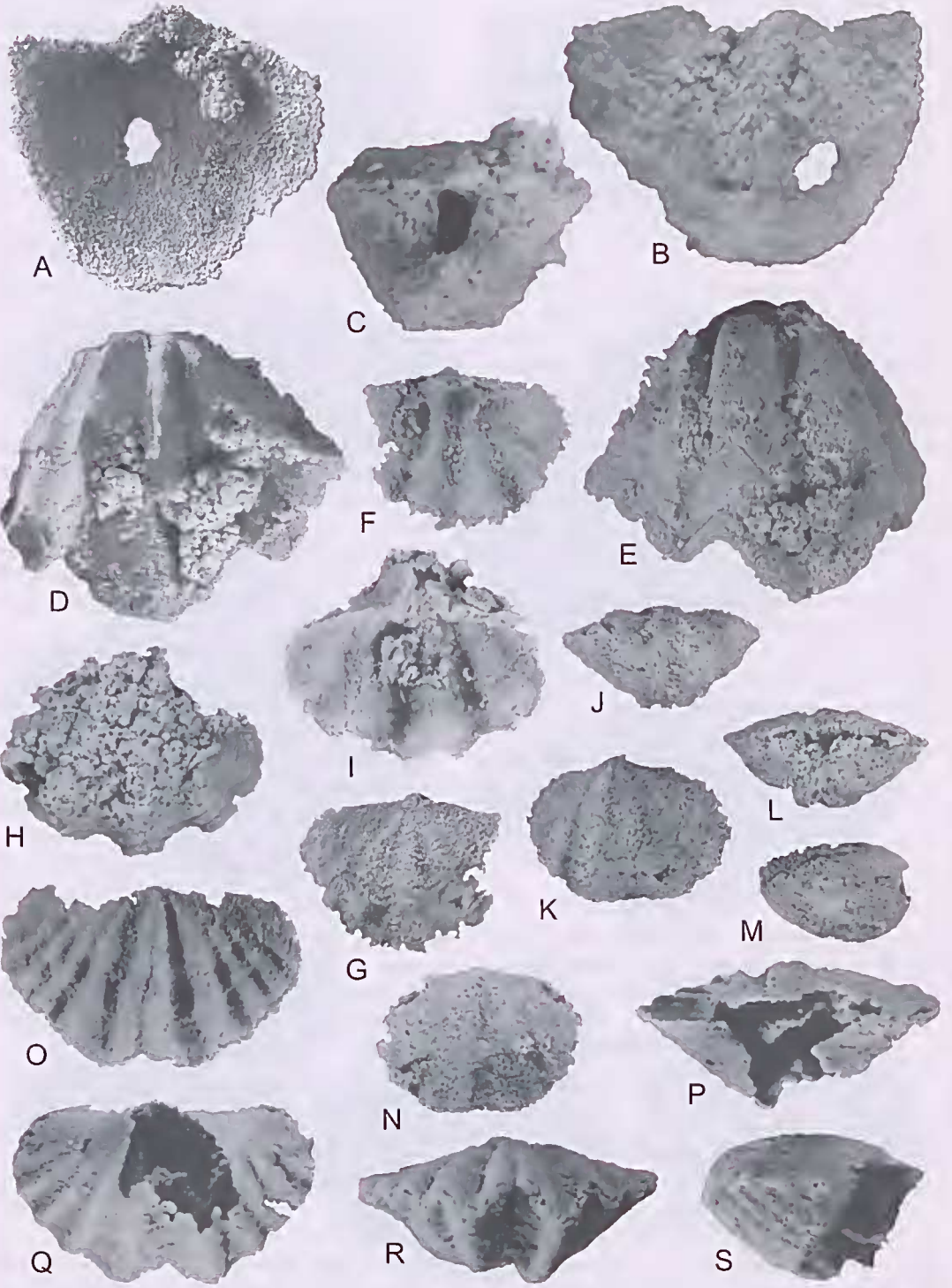
Description. See Chatterton (1973: 99).

Remarks. Chatterton (1973) assigned this species from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas to *Ambothyris* George, 1931 as it closely matched Havlíček's (1959b: 176) diagnosis for *Ambothyris*, only differing in possessing a rod-like plate in the apex of the delthyrium and the crural plates are not united to form a eruralium. Examination of Chatterton's (1973: pl. 19, figs 13, 14) figured material however indicates that crural plates are lacking in *A. runnegari*. As in the Murrindal specimens, the crura appear to be supported by erural bases only, which extend forward for about one third of the shell length (Fig. 17H). Following Carter et al. (1994), this species is therefore re-assigned to *Ambocoelia*.

Although closely resembling *A. runnegari* in terms of profile, outline and ornament, the Murrindal specimens differ from Chatterton's (1973) material in possessing more variably developed dorsal and ventral valve sulci and lack the rod-like plate in the apex of the delthyrium (Fig. 18B, C). Only one specimen shows any trace of median ridge in the ventral valve (Fig. 18B). However, as few of the Murrindal specimens are free from secondary infilling, it is not possible to determine the presence of absence of a median ridge in the ventral valve. Comparison of microornament is not possible as none has been preserved in the Murrindal specimens. Alternatively, the Murrindal specimens may represent a new species closely related to *A. runnegari*.

Suborder DELTHYRIDINA Ivanova, 1972
Superfamily DELTHYRIDOIDEA Phillips, 1841
Family DELTHYRIDIDAE Phillips, 1841
Subfamily DELTHYRIDINAE Phillips, 1841

Fig. 17. A, B, *Spinella buchaneensis buchaneensis* Talent, 1956a, dorsal valve interior and exterior, ROC 159, AM F117298, x 3. C-G, *Spinella yassensis* (de Koninck, 1876), anterior, dorsal, ventral, posterior and lateral views of articulated specimen, ROC 165, AM F117299, x 7. H, I, *Ambocoelia* sp. cf. *A. runnegari* (Chatterton, 1973), dorsal valve interior and exterior, MeL 520, AM F117300, x 20.



Delthyris Dalman, 1828

Type species. By original designation of Dalman (1828: 120); *Delthyris elevata* Dalman, 1828; Silurian of Gotland.

Delthyris? sp.

Fig. 18D, E

Material. Figured material: AM F117303 (Fig. 18D); ventral valve from MeL 520. Unfigured material: six ventral valves.

Remarks. The plications of these specimens range from low and rounded to high and subangular, with well-developed growth lines (Fig. 18E). Internally, well-developed dental plates are present in at least one specimen and muscle scar impressions are lacking. These features, and their variability, are all reminiscent of *Cyrtina wellingtonensis* Dun, 1904, which has also been recovered from the Murrindal Limestone. However, these specimens have been tentatively assigned to *Delthyris* on the presence of a median septum in the ventral valve that terminates abruptly around valve midlength (Fig. 18D). In two specimens, the median septum appears to have a serrated anterior margin. These features suggest the affinities of this species lies with *Delthyris hudsoni* Chatterton, 1973, from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas. Additional material is required for a more positive identification.

Subfamily HOWELLELLINAE Johnson & Hou (in Carter, Johnson, Gourvennee & Hou, 1994)

Howellella (Howellella) Kozłowski, 1946

Type species. By original designation of Kozłowski (1946: 295); *Delthyris elegans* Muir-Wood, 1925; Middle Silurian of Anglie.

Howellella (Howellella) textilis Talent, 1963

Fig. 18E-M

Howellella textilis n. sp. Talent 1963: 81, pl. 50, figs 1-43.

Howellella cf. *textilis*-Johnson 1970a: 186, pl. 55, figs 1-19.-Chatterton 1973: 106, pl. 27, figs 1-19.-Lenz & Johnson 1985b: 89, pl. 12, figs 10-22.

Howellella (Howellella) textilis-Brock 2003b: 81, pl. 11, figs 11-16.

Material. Figured material: AM F117304 (Fig. 18E, F); ventral valve from MeL 420dh; AM F117305 (Fig. 18G, H); dorsal valve from MeL 420dh; AM F117306 (Fig. 18I-M); articulated specimen from MeL 420dh. Unfigured material: 62 ventral valves, 37 dorsal valves and 21 articulated specimens.

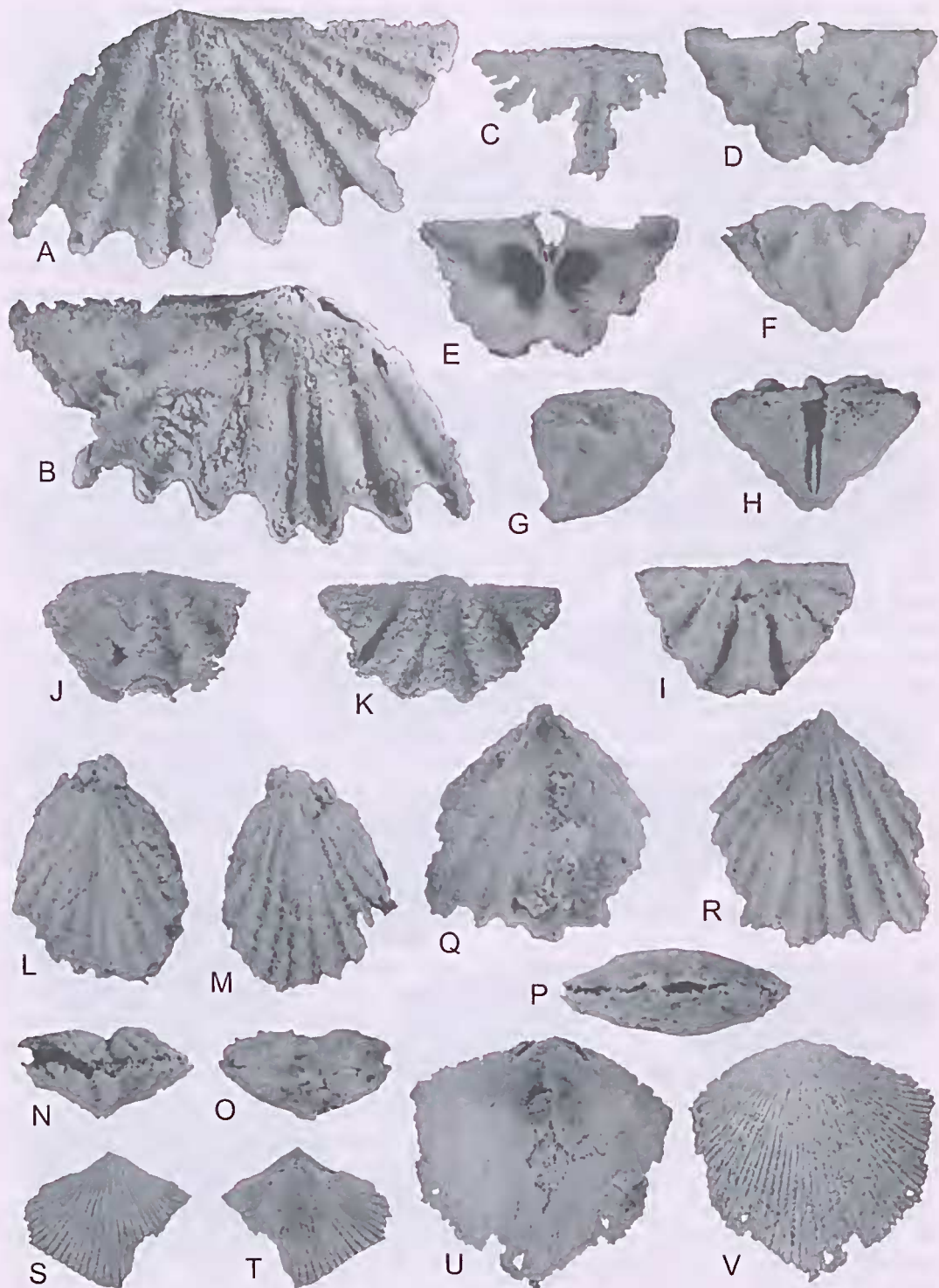
Description. See Talent (1963: 81).

Remarks. Most of the specimens recovered from the Murrindal Limestone closely resemble *H. (H.) textilis* from the late Pragian Lower Kilgower Member of the Tabberabbera Formation, differing only in some cases by possessing a greater number of plications and being slightly larger. However, these forms grade into forms identical to those described by Talent (1963).

Several species of *Howellella* have been reported from the Early Devonian Garra Limestone of New South Wales (Savage 1969; Lenz & Johnson 1985b; Farrell 1992; Brock 2003b). Of these, *H. (H.) textilis* appears most closely related to *H. nucula australis* Savage, 1969, but differs in possessing more plications, a stronger fold and sulcus and by being more transverse (Chatterton 1973). *Howellella talenti* Farrell, 1992 differs in possessing less prominent growth lamellae, lacking a myopliragm in the ventral valve and crural plates that are convergent posteriorly and dorsally (Farrell 1992).

Mawson & Talent (1999) described four species of *Howellella*, *H. placocotextilis*, *H. alatextilis*, *H. legirupa* and *H. sp.* from the Lochkovian Windellama Limestone of New South Wales. Both *H. placocotextilis* and *H. alatextilis* appear to be closely related to *H. (H.) textilis*, but are distinguishable by differences in the ornament, with *H. (H.) textilis* having much narrower plications than the former and fewer plications than the latter. *Howellella alatextilis* also differs by being strongly alate (Mawson

Fig. 18. A-C, *Ambocoelia* sp. cf. *A. runnegari* (Chatterton, 1973). All specimens x 20. A, B, ventral valve interior and exterior, MeL 520, AM F117301. C, posterior view of articulated specimen, MeL 520, AM F117302. D, E, *Delthyris?* sp., ventral valve interior and exterior, MeL 520, AM F117303, x3. E-M, *Howellella (Howellella) textilis* Talent, 1963. All specimens x 7. F, G, dorsal valve interior and exterior, MeL 420dh, AM F117305. H, I, ventral valve interior and exterior, MeL 420dh, AM F117304. J-N, anterior, ventral, posterior, lateral and dorsal views of articulated specimen, MeL 420dh, AM F117306. O-S, *Howittia howitti* (Chapman, 1905), posterior, ventral, anterior and lateral views of articulated specimen, ROC 159, AM F117307, x7.



& Talent 1999). Whereas *H. legirupa* has a similar number and type of plications as *H. textilis*, it differs internally by possessing significantly larger dental plates as pointed out by Sherwin (1995).

Howittia Talent, 1956a

Type species. By original designation of Talent (1956a: 34); *Spirifer howitti* Chapman, 1905; latest Pragian to early Emsian of the Buchan Caves Limestone, Bindi, Victoria, Australia.

Howittia howitti (Chapman, 1905)

Figs 18N-R, 19A, B

Spirifer howitti sp. nov. Chapman 1905: 18, pl. 5, figs 4-6.

Howittia howitti-Talent 1956a: 34, pl. 2, figs 13-17. Chatterton 1973: 112, pl. 24, figs 1-20.

Howittia cf. *H. howitti*-Lenz & Johnson 1985b: 90, pl. 14, figs 14-21.

Material. Figured material: AM F117307 (Fig. 18N-R); articulated specimen from ROC 159; AM F117308 (Fig. 19A, B); dorsal valve from ROC 159. Unfigured material: 10 ventral valves and three dorsal valves.

Description. See Chapman (1905: 18), Talent (1956a: 34) and Chatterton (1973: 112).

Remarks. These specimens can be readily assigned to *H. howitti* on the basis of the medial plication of the dorsal valve bearing a distinct groove, a feature Chapman (1905: 18) described as being one of the chief characteristics of *H. howitti*. *Howittia howitti* is very similar to *H. multiplicata* (de Koninek, 1876) from the Emsian limestones at Taemas (de Koninek 1876; Chatterton 1973) and the Lick Hole Formation at Ravine (Strusz et al. 1970), in terms of outline, microornament, delthyria, lateral plates and the subdivided fold and sulcus. However, they differ in that *H. multiplicata* has more plications, the fold of a mature dorsal valve is subdivided by at least five

furrows and that the plications next to the fold and sulcus of *H. multiplicata* are usually subdivided near the umbo. Internally, *H. multiplicata* has shorter crural plates (Chatterton 1973).

Howittia haideri Soja, 1988, from the Emsian of Kasaan Island, southeastern Alaska, differs from *H. howitti* in being smaller, having fewer plications and with three plications consistently on the fold and two in the sulcus. Internally, the two species are virtually identical, but *H. haideri* has much thicker dental plates. An unnamed species of *Howittia* described by Perry (1984), from Emsian strata of the Delorme Formation of Canada, differs in possessing less prominent ventral valve adminicula and fewer plications. A second unnamed species of *Howittia*, described by Johnson (1971) from the Emsian of the Sulphur Spring Range of central Nevada, possesses fewer and stronger plications. In addition, the plication on the sulcus is much larger than in *H. howitti* (Johnson 1971).

Numerous species of *Howittia* have also been described from China, many of which occur in the early Emsian Nanning-Liujing district of central Guangxi in southern China (Wang & Rong 1986). They consistently differ from *H. howitti* in possessing fewer plications, up to eight at most. In addition, most species also possess more plications in the fold and grooves in the sulcus than *H. howitti*, and lack growth lamellae developed over the entire shell.

Order SPIRIFERINIDA Ivanova, 1972

Remarks. The higher level classification used for the Spiriferinida herein follows that of Carter et al. (1994).

Suborder CYRTINIDINA Carter & Johnson (in Carter, Johnson, Gourvennee & Hou 1994)
Superfamily CYRTINOIDEA Frederiks, 1911
Family CYRTININAE Frederiks, 1911

Cyrtina Davidson, 1858a

Type species. By subsequent designation of Hall & Clarke (1894: 44); *Calceola heteroclitia* DeFrance, 1824; Middle Devonian of western Europe.

Fig. 19. A, B, *Howittia howitti* (Chapman, 1905), dorsal valve exterior and interior, ROC 159, AM F117308, x 7. C-K, *Cyrtina wellingtonensis* Dun, 1904. All specimens x 5. C, dorsal valve interior, MeL 420dh, AM F117310. D, E, ventral valve exterior and interior, MeL 420dh, AM F117309. F-I, anterior, lateral, posterior and dorsal views of articulated specimen, ROC 162, AM F117311. J, dorsal valve exterior, MeL 420dh, AM F126356. K, dorsal view of articulated specimen, ROC 165, AM F126357. L-R, *Coelospira dayi* Chatterton, 1973. All specimens x 7. L-P, dorsal, ventral, anterior, posterior and lateral views of articulated specimen, MeL 497, AM F117312. Q, R, ventral valve interior and exterior, MeL 497, AM F117313. S-V, *Variatrypa (Variatrypa) erectirostris* (Mitchell & Dun, 1920). All specimens x 2. S, T, ventral valve exterior and interior, MeL 417, AM F117314. U, V, dorsal valve interior and exterior, ROC 162, AM F117315.

Cyrtina wellingtonensis Dun, 1904
Fig. 19C-K

- Cyrtina wellingtonensis* sp. nov. Dun 1904: 319, pl. 61, fig. 2–2e.-Broek 2003b: 85, pl. 9, figs 15–19; pl. 10, figs 1–4.
- Cyrtina* aff. *C. wellingtonensis*-Chatterton 1973: 101, pl. 23, figs 1–25.
- ?*Cyrtina* sp. 1 Lenz & Johnson 1985b: 87, pl. 11, figs 10–13.
- Cyrtina* sp. 2 Lenz & Johnson 1985b: 88, pl. 11, figs 14–17, 22.
- ?*Cyrtina* sp. 3 Lenz & Johnson 1985b: 88, pl. 11, figs 18–20, 22–25, 29.
- Cyrtina* sp. Broek & Talent 1993: 244, fig. 15A-E.

Material. Figured material: AM F117309 (Fig. 19D, E): ventral valve from MeL 420dh; AM F117310 (Fig. 19C): dorsal valve from MeL 420dh; AM F117311 (Fig. 19F-I): articulated specimen from ROC 162; AM F126356 (Fig. 19J): dorsal valve from MeL 420dh; AM F126357 (Fig. 19K): articulated specimen from ROC 165. Unfigured material: 98 ventral valves, 70 dorsal valves and 157 articulated specimens.

Description. See Dun (1904: 319) and Chatterton (1973: 101).

Remarks. *Cyrtina* is a cosmopolitan genus that exhibits a high degree of intraspecific variation, leading to great difficulties in distinguishing between species, not only within each collection, but also between collections. Kozłowski (1929), Chatterton (1973), Lenz (1977b), Perry (1984), Lenz & Johnson (1985b), Farrell (1992) and Broek (2003b) have all commented on these difficulties. This variation is so great that Lenz & Johnson (1985b) merely divided their specimens of *Cyrtina* from the Pragian Garra Limestone at Wellington into three unnamed species. Perry (1984) did not even attempt to identify individual species, claiming that only through the statistical analysis of large collections could individual species be accurately identified. Such a study has yet to be undertaken.

The specimens assigned to *Cyrtina* from the Murrindal Limestone have proved no exception to this rule. Like most *Cyrtina*, the interareas of the Murrindal specimens range from flat to strongly curved (Fig. 19D, E, G, H, I, K); the plications are weakly to strongly developed and rounded to angular (Fig. 19D, F, G, I, J, K); concentric growth lines

are faint and subdued to strongly developed (Fig. 19E, G, I, J, K); the cardinal extremities are rounded to angular (Fig. 19E, I, J, K); and some beaks are slightly twisted. As observed by Farrell (1992), these differences may be environmental in origin, a result of growth in a crowded environment, producing distorted shell growth.

Size has been frequently used to compare specimens of *Cyrtina* from different collections and to distinguish between different species (eg. Savage 1969; Farrell 1992). However, this appears to be an unreliable method of discriminating between individual species of *Cyrtina* as the size of many established species appears very similar. Broek (2003b: 86) has also shown that size can vary greatly intraspecifically.

A comparison of size versus the number of plications on the ventral and dorsal valves appears to separate eastern Australian specimens of *Cyrtina* into several distinct groups (Fig. 20). This analysis groups the Murrindal specimens with *C. wellingtonensis* from the Garra Limestone at Wellington (Dun 1904), *Cyrtina* sp. 2 from the Garra Limestone at Wellington (Lenz & Johnson 1985b), *C. wellingtonensis* from the Garra Limestone at Eurimbla (Broek 2003b), *Cyrtina* aff. *C. wellingtonensis* from the Emsian 'Receptaculites' and Warroo Limestone Members of the Taemas Limestone at Taemas (Chatterton 1973), and *Cyrtina* sp. from the Emsian Ukalunda Beds of Queensland (Broek & Talent 1993). The Murrindal specimens have therefore been assigned to *C. wellingtonensis*.

This analysis also allows the Murrindal specimens to be separated from *C. heteroclita*, *C. imbricata* Farrell, 1992 from the Garra Limestone of New South Wales (Savage 1969; Farrell 1992) and *C. praecedens* Kozłowski, 1929 from the Windellama Limestone in New South Wales (Mawson & Talent 1999) (Fig. 20).

Cyrtina sp. 2 and 3, described by Lenz & Johnson (1985b) from the Garra Limestone of New South Wales, plot slightly outside the range determined for *C. wellingtonensis* in this study (Fig. 20). Analysis of additional material is required to determine if these species also belong to *C. wellingtonensis*.

Order ATRYPIDA Rzhonsnitskaya, 1960
Suborder ATRYPIDINA Moore, 1952
Superfamily ATRYPIDEA Gill, 1871
Family ATRYPIDAE Gill, 1871
Subfamily ATRYPINAE Gill, 1871

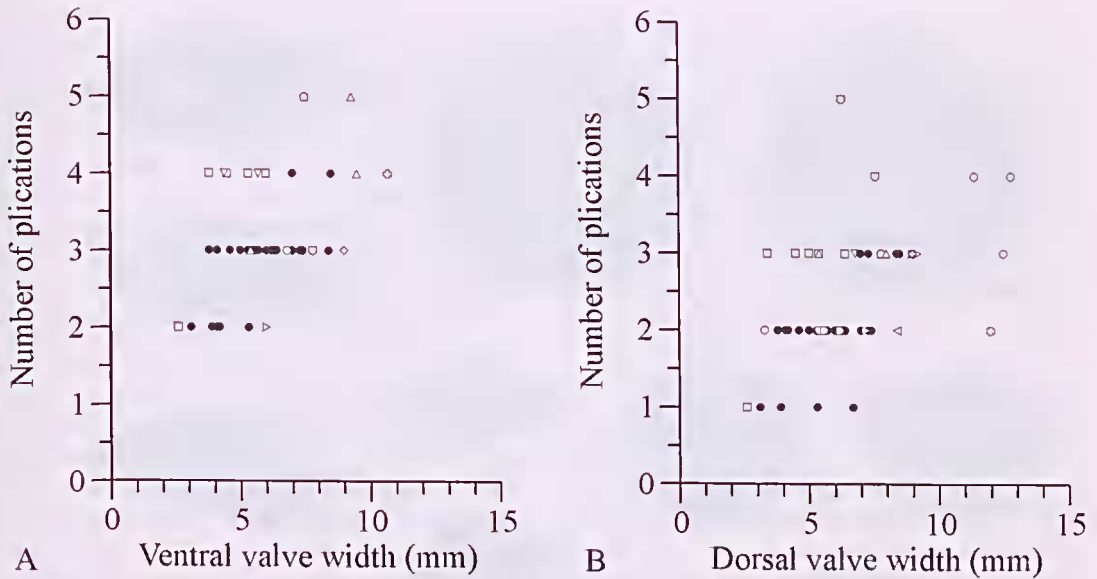


Fig. 20. Number of plications versus A, ventral valve width and B, dorsal valve width, for various Early Devonian species of *Cyrtina* from eastern Australia. ● *C. wellingtonensis* from the Murrindal Limestone, Buchan (A, $n = 29$; B, $n = 29$); ◇ *C. wellingtonensis* from the Garra Limestone, Wellington (A, $n = 1$; B, $n = 1$) (Dun 1904: pl. 61, fig. 2); ○ *C. aff. C. wellingtonensis* from the 'Receptaculites' and Warroo Limestone Members of the Tacmas Limestone, Taemas (A, $n = 1$; B, $n = 5$) (Chatterton 1973: pl. 23, figs 1–25). ◁ *Cyrtina* sp. 1 from the Garra Limestone, Wellington (A, $n = 0$; B, $n = 1$) (Lenz & Johnson 1985b: pl. 11, figs 10–13); *Cyrtina* sp. 2 from the Garra Limestone, Wellington (A, $n = 0$; B, $n = 2$) (Lenz & Johnson 1985b: pl. 11, figs 14–17, 21); ▷ *Cyrtina* sp. 3 from the Garra Limestone, Wellington (A, $n = 1$; B, $n = 4$) (Lenz & Johnson 1985b: pl. 11, figs 18–20, 22–25, 29); *Cyrtina* sp. from the Ukalunda Beds, northeast Queensland (A, $n = 1$; B, $n = 1$) (Brock & Talent 1993: fig. 15A–E); △ *C. wellingtonensis* from the Garra Limestone, Eurimbla (A, $n = 3$; B, $n = 2$) (Brock 2003b); □ *C. praecedens* from the Mandagery Park Formation, Manildra (A, $n = 6$; B, $n = 6$) (Savage 1969: pl. 92, figs 1–44); *C. praecedens* from the Windellama Limestone, Windellama (A, $n = 2$; B, $n = 1$) (Mawson & Talent 1999: pl. 9, figs 15–19); *C. imbricata* from the Garra Limestone, The Gap (A, $n = 1$; B, $n = 3$) (Farrell 1992: pl. 5, figs 13–26); *Calceola heterochlita*, type species of *Cyrtina* (A, $n = 1$; B, $n = 1$) (Boucot et al. 1965: fig. 549, 10).

Atryparia Copper, 1966a

Type species. By original designation of Copper (1966a: 982); *Atryparia instita* Copper, 1966a; late Eifelian Müllert horizon, Ahbaeh beds, Germany.

Atryparia penelopeae (Chatterton, 1973)

Fig. 21F–V

Atrypa desquamata Mitchell & Dun 1920: 271, pl. 15, figs 12, 13.

Desquamatia (Synatrypa) sp. nov. Hill, Playford & Woods 1967: pl. 20, figs 15, 16.

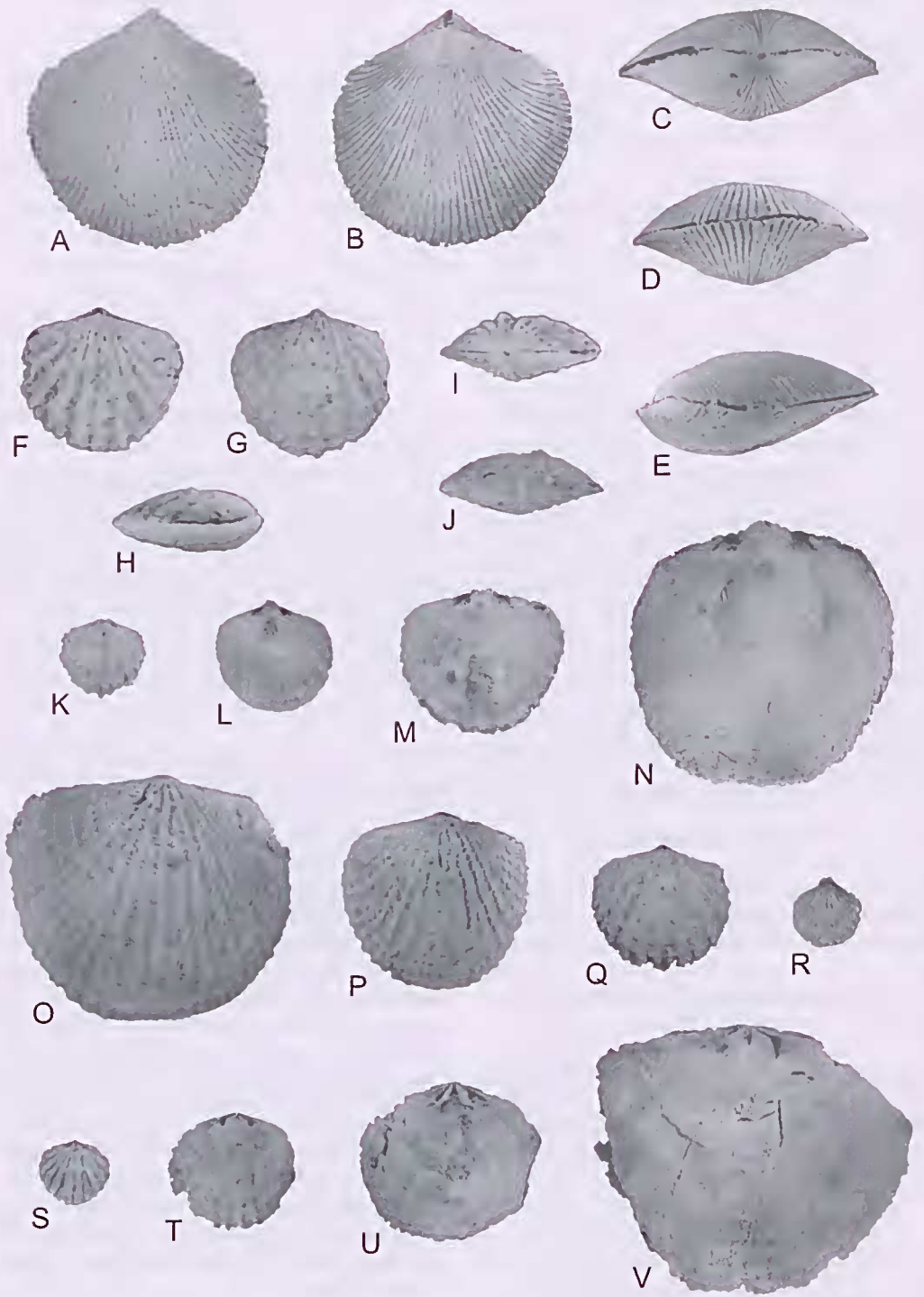
Atrypa penelopeae sp. nov. Chatterton 1973: 87, pl. 20, figs 15, 16; pl. 21, figs 12–23, 25–29; pl. 22, figs 1–10.

Desquamatia (Variatrypa) cf. *penelopeae*–Lenz & Johnson 1985b: 78, pl. 4, figs 4–14.

Atryparia penelopeae–Brock & Talent 1993: 239, fig. 11P–R; fig. 12A–J.

Material. Figured material: AM F117317 (Fig. 21F–J); articulated specimen from ROC 162; AM F117318 (Fig. 21K); ventral valve from ROC 162; AM F117319 (Fig. 21L); ventral valve from ROC 162; AM F117320 (Fig. 21M); ventral valve from ROC 162; AM F117321 (Fig. 21N); ventral valve from ROC 181; AM F117322 (Fig. 21O); articulated specimen from McL 417; AM F117323 (Fig. 21P); articulated specimen from McL 417; AM F117324 (Fig. 21Q); articulated specimen from ROC 162; AM F117325 (Fig. 21R); articulated specimen from ROC 162; AM F117326 (Fig. 21S); dorsal valve from ROC 162; AM F117327 (Fig. 21T); dorsal valve from ROC 162; AM F117328 (Fig. 21U); dorsal valve from ROC 162; AM F117329 (Fig. 21V); dorsal valve from ROC 162. Unfigured material: 779 ventral valves, 790 dorsal valves and 772 articulated specimens.

Description. See Chatterton (1973: 87).



Remarks. Broek & Talent (1993) believed the shape, growth lines, beak shape, lack of deltidial plates in mature specimens and the secondary thickening of shell material in the delthyrium of this species suggested its affinities lay with *Atryparia*, rather than *Atrypa* Dalman, 1828, where it was originally assigned by Chatterton (1973). Affinities with *Variatrypa* Copper, 1966b can be ruled out as the frill is not composed of a single piece. Unlike *Desquamatia* Aleksceva, 1960, adult specimens of *A. penelopeae* lack a well-developed interarea and possess coarse, rather than fine, costae.

Talent et al. (2001) questionably referred *A. penelopeae* to *Peetzatrypa* Rzhonsnitskaya, 1975, which occurs in the Eifelian Poluiakhtovsk Beds of the southwestern margin of the Kuzbass. *Peetzatrypa* possesses deltidial plates that are lacking in mature specimens of *A. penelopeae*, and weakly developed dental plates, that are thick and well developed in *A. penelopeae*. *Peetzatrypa* also possesses a high dorsal valve median ridge and spiralia with around ten whorls. *Atryparia penelopeae* has only a low dorsal valve median ridge, which is restricted to dividing the posterior half of the adductor scars and spiralia with as many as nineteen whorls (Chatterton 1973). Copper (2002) has recently synonymised *Peetzatrypa* with *Variatrypa*.

Ontogeny. Neanic specimens of *A. penelopeae* from the Murrindal Limestone are equibiconvex, or slightly ventribiconvex. A weakly developed fold in the ventral valve and sulcus in the dorsal valve may be present. A small pair of deltidial plates are observable in the delthyrium, defining a small, circular foramen (Fig. 21R). Several equally spaced growth lines are also observable with more added at regular intervals throughout growth (Fig. 21R). Muscle scars, if present, are only faintly impressed in each valve. The inner surface is strongly erenulate, a reflection of external ornament (Fig. 21K, S).

The dorsal valve of sub-adults has increased in convexity relative to the ventral valve, making them dorsibiconvex (Fig. 21H). The delthyrium, with its circular foramen and deltidial plates is still observable, but has begun to be reabsorbed (Fig. 21Q). Additional costae have arisen through intercalation and bifurcation (Fig. 21P, Q). Muscle scars are only

faintly impressed, with the ventral valve muscle scars being more firmly impressed than those of the dorsal valve (Fig. 21L, M, T, U). Slight pitting occurs in the ventral valve muscle field of some specimens, usually in those with the more firmly impressed muscle scars. The teeth have developed a faintly erenulate ridge running along their length and corresponding erenulated furrows are developed in the sockets of the dorsal valve (Fig. 21M, U). The internal surfaces have lost the strongly erenulated appearance, becoming smoother as the shells increase in size (Fig. 21L, M, T, U).

In adult and gerontic forms, the pedicle has been atrophied and the deltidial plates and foramen are absent, both having been resorbed (Fig. 21N, O). In association with this, secondary thickening of the shell around the delthyrium is prominent. The profile of adult *A. penelopeae* is strongly dorsibiconvex, the ventral valve being almost planar in some specimens. The muscle scars of both valves have become even more deeply impressed, but those of the dorsal valve are less firmly impressed than those of the ventral valve (Fig. 21N, V). A low ridge dividing the posterior portion of the dorsal valve muscle field has also been developed (Fig. 21V). The area around the muscle scars of both valves has become pitted, especially in the ventral valve (Fig. 21N). Stronger pitting is usually associated with more deeply impressed muscle scars. A frill is also developed in some adult and gerontic specimens of *A. penelopeae*.

Subfamily VARIATRYPINAE Copper, 1978

Variatrypa (*Variatrypa*) Copper, 1966b

Type species. By original designation of Copper (1966b: 12); *Desquamatia ajungata* Copper, 1965; lower Givetian Neuenbüsch horizon of the Blankenheim Syncline, northern Eifel, Germany.

Remarks. Copper (1966b) established *Variatrypa* as a subgenus of *Desquamatia*, but subsequently raised it to generic level (Copper 1978, 1991, 2002), diagnosing it as large, shield-shaped, dorsibiconvex with only one or two growth lines and a frill that is normally a single piece. According to Copper (1978: 294), *Anatrypa* may be distinguished from *Variatrypa* by its

Fig. 21. A-E, *Variatrypa* (*Variatrypa*) *erectirostris* (Mitchell & Dun, 1920), ventral, dorsal, posterior, anterior and lateral views of articulated specimen, MeL 417, AM F117316, x 2. F-V, *Atryparia penelopeae* (Chatterton, 1973). All specimens x 2. F-J, dorsal, ventral, lateral, posterior and anterior views of articulated specimen, ROC 162, AM F117317. K-N, all ventral valve interiors. K-M, ROC 162, N, ROC 181, AM Fs117318-117321. O-R, all dorsal view of articulated specimens. O, P, MeL 417, Q, R, ROC 162, AM Fs 117322-117-325. S-V, all dorsal valve interiors, ROC 162, AM Fs 117326-117329.

biconvex profile, transversely subpentagonal outline, deltidial plates supported well into the interior of the pedicle cavity, medially directed teeth, thinner hinge plates, weakly developed cardinal process and thicker, ventrally directed erural bases. In contrast, Johnson & Boueot (1968) and Johnson (1970b, 1974a) argued that *Variatrypa* is best regarded as a subgenus of *Anatrypa*, due to similarities in ornament, the ventral valve interarea and delthyrium. The differences in shell shape between the type species of *Anatrypa* and *Variatrypa* were considered by Johnson & Boueot (1968) to be insignificant at the generic level. However, based on the differences discussed above, there seems sufficient differences between *Variatrypa* and *Anatrypa* to warrant a separate generic status for each.

Variatrypa (Variatrypa) erectirostris
(Mitchell & Dun, 1920)
Figs 19S-V, 21A-E

Atrypa erectirostris Mitchell & Dun 1920: 267, pl. 15, figs 10, 11; pl. 16, figs 17, 18.

Anatrypa erectirostris-Chatterton 1973: 92, pl. 20, figs 1-14, 17; pl. 21, figs 1-11, 24, 30-32; pl. 22, figs 11, 12.

Variatrypa (Variatrypa) erectirostris-Broek & Talent 1993: 243, fig. 12K-O; fig. 13 F-P.

Material. Figured material: AM F117314 (Fig. 19S, T): ventral valve from MeL 417; AM F117315 (Fig. 19U, V): dorsal valve from ROC 162; AM F117316 (Fig. 21A-E): articulated specimen from MeL 417. Unfigured material: 70 ventral valves, 30 dorsal valves and 106 articulated specimens.

Description. See Mitchell & Dun (1920: 267) and Chatterton (1973: 92).

Remarks. Chatterton (1973) declined to place this species from the Emsian 'Receptaculites' Limestone Member at Taemas, into either of the subgenera proposed by Copper (1966b) for *Anatrypa*. Chatterton (1973) believed this species to be larger than *A. (Synatrypa)* and possessing a ventral valve that is concave anterolaterally (Fig. 21C, D), and to be distinct from *A. (Variatrypa)* because it lacked a frill and possesses finer and more closely spaced costae (Figs 19S, V, 20A, B). However, Chatterton (1973) did note this species is probably closest to those forms assigned to *A. (Variatrypa)*. Broek & Talent (1993) provisionally reassigned this species to *Variatrypa (Variatrypa)*, following Copper (1978, 1991),

on the basis of the fine ribbing being interrupted by only a few growth lamellae. In addition, some specimens from the Murrindal Limestone, unlike those described by Chatterton (1973), possess growth lamellae developed into frills, further reinforcing this species' affinities with *Variatrypa*.

Suborder DAYIINA Waagen, 1883
Superfamily ANOLOTHECOIDEA
Schuchert, 1894

Family ANOLOTHECIDAE Schuchert, 1894

Remarks. Following Johnson (1974b), Dagys (1996), Alvarez & Carlson (1998) and Alvarez et al. (1998), the Anoplotheceidae (which includes *Coelospira* Hall, 1863, discussed below) are assigned to the superfamily Anoplotheceida (following Alvarez et al. 1998) within the suborder Dayiina (following Johnson 1974b) in the order Atrypida. Although fundamental differences do exist between the Dayiina and the other atrypid suborders, and confusion surrounds their evolutionary relationships, there appears little justification at present to warrant their inclusion within the Athyrida as proposed by Copper (1973, 1986), Copper & Gourvennee (1996) and Alvarez & Copper (2002).

Subfamily COELOSPIRINAE Hall & Clark, 1895

***Coelospira* Hall, 1863**

Type species. By original designation of Hall (1863: 60); *Leptocoelia concava* Hall, 1857; Loehkovic of the lower Helderberg Group, Helderberg Mountain, New York, America.

***Coelospira dayi* Chatterton, 1973**
Fig. 19L-R

Coelospira dayi sp. nov. Chatterton 1973: 84, pl. 19, figs 15-36; pl. 35, figs 6-8.

Material. Figured material: AM F117312 (Fig. 19L-P): articulated specimen from MeL 497; AM F117313 (Fig. 19Q, R): ventral valve from MeL 497. Unfigured material: four ventral valves and 12 articulated specimens.

Description. See Chatterton (1973: 84).

Remarks. *Coelospira concava* (see Boueot & Johnson 1967: 1235-1236 for locality information) shows considerable morphological variation, espe-

cially in the length to width ratio and in the character of the median rib of the ventral valve. *Coelospira dayi* differs most consistently from *C. concava* in having a ventral valve muscle field that is not anteriorly elevated on a platform.

Coelospira dayi was the first species of *Coelospira* to be documented in Australia. Previously, Devonian *Coelospira* were believed to have been restricted to Laurentia, apart from a single specimen recovered from Turkey (Boucot & Johnson 1967). However, since then *Coelospira* has also been recovered from northern Mexico, South America and Asia, ranging from Loehkovian to Eifelian in age (Alvarez & Copper 2002). Several additional species of *Coelospira* have also been described from Australia.

Coelospira praedayi Lenz & Johnson, 1985b, from the Pragian Garra Limestone at Wellington is closely related to *C. dayi*. Both species have a similar shape and ornament, but *C. dayi* is more elongate, possesses a shorter median costa on the ventral valve and shorter, weaker secondary costae. *Coelospira septata* Lenz & Johnson, 1985b, also from the Pragian Garra Limestone at Wellington (Lenz & Johnson 1985b) and the Pragian Garra Limestone at Eurimbla (Broek 2003b), is more rounded, possesses more costae in the dorsal valve sulcus compared to *C. dayi* and has a thread-like median ridge in the ventral valve and a prominent median septum in the dorsal valve (Lenz & Johnson 1985b). An indeterminate specimen referred to as *Coelospirinae* gen. indet. by Savage (1974) from the ?early Loehkovian Maradana Shale has been referred to *Coelospira* by Talent et al. (2001). This species differs primarily from *C. dayi* in bearing more costae.

Coelospira sp. documented by Broek & Talent (1993) from the Emsian Ukalunda Beds and Douglas Creek of Queensland, possesses a similar outline, incurvature of the beak and growth lines to *C. dayi*. However, *C. dayi* is distinguishable by its well-developed dorsal valve sulcus (Fig. 19L, N) and ventral valve with a fine medial plication flanked by a pair of large costae (Fig. 19M, R). The Ukalunda and Douglas Creek specimens also possess a number of features unique to *Coelospira*, such as the presence of up to three well-developed ventral medial costae and costae which increase by bifurcation on the ventral valve and usually by implantation on the dorsal valve. Broek & Talent (1993: 239) speculated that this unusual combination of features may indicate these specimens represent a new species of *Coelospira*, but additional material is required to confirm this. Hill et al. (1967: pl. D12, fig. 6) figured a single specimen of *Coelospira* from the

Ukalunda Beds that appears externally similar to those specimens described by Broek & Talent (1993), although it has a somewhat narrower outline.

Order ATHYRIDIDA Boucot, Johnson & Stanton, 1964

Suborder ATHYRIDINA Boucot, Johnson & Stanton, 1964

Superfamily ATHYRIDOIDEA Davidson, 1881

Family ATHYRIDIDAE Davidson, 1881

Subfamily DIDYMOTHYRIDINAE
Modzalevskaia, 1979

Buchanathyris Talent, 1956a

Type species. By original designation of Talent (1956a: 36); *Buchanathyris westoni* Talent, 1956a; Early Emsian Buchan Caves Limestone, Buchan, Victoria, Australia.

Buchanathyris westoni Talent, 1956a

Fig. 22A-J

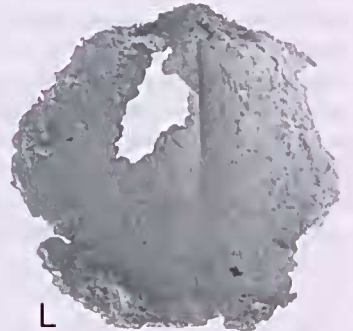
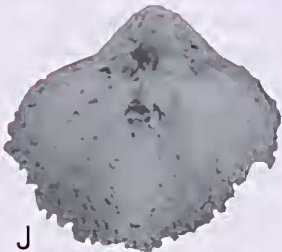
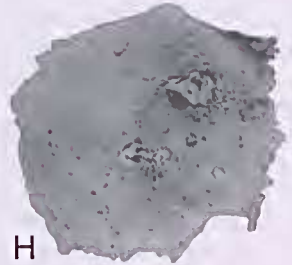
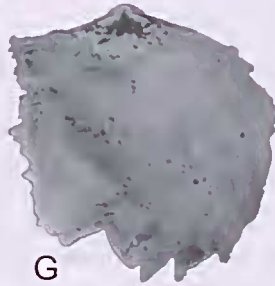
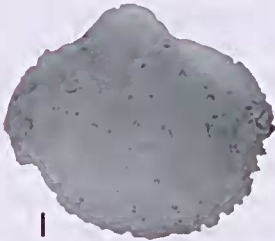
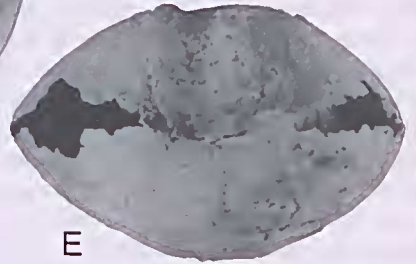
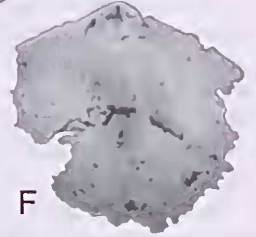
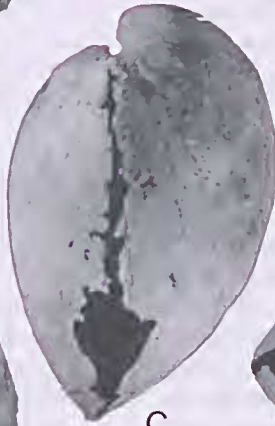
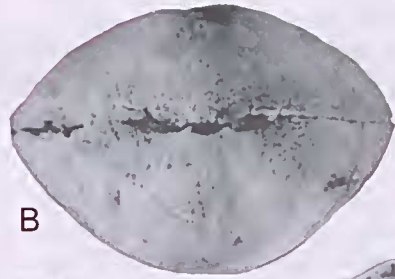
Buchanathyris westoni sp. nov. Talent 1956a: 36, pl. 3, figs 1-4.

Buchanathyris westoni?-Talent 1963: 87, pl. 59, figs 5-11.

Material. Figured material: AM F117330 (Fig. 22A-E): articulated specimen from ROC 162; AM F117331 (Fig. 22F): dorsal valve from ROC 162; AM F117332 (Fig. 22G, H): dorsal valve from ROC 165; AM F117333 (Fig. 22I, J): ventral valve ROC 162. Unfigured material: 210 ventral valves, 229 dorsal valves and 32 articulated specimens.

Description. See Talent (1956a: 36).

Remarks. Although no features of the lophophore support or jugum have been preserved, the presence of a short and apically perforated hinge plate, fairly well developed concave dental plates and lack of a median septum (Fig. 22F, G, J), indicates the affinities of this taxon lie with *Buchanathyris*. The ornament, consisting of fine concentric growth lines at best (Fig. 22A, D), associates these specimens with *B. westoni*, which also occurs in the early Emsian Buchan Caves Limestone and Pragian Dead Bull Member of the Tabberabbera Formation of Victoria (Talent 1956a). The ornament also separates this species from *B. waratahensis* Talent, 1956a, from the latest Pragian Bell Point



Limestone in Victoria, which possesses projecting growth lines. *Buchanathyris? pulchra* Talent, 1963 (questionably referred to *Athyris?* by Talent et al. 2001) from the ?early Emsian Roaring Mag Member of the Tabberabbera Formation of Victoria, differs from *B. westoni* in possessing a well defined sulcus in the ventral valves, a poorly developed fold in the dorsal valve and well developed growth lamellae.

The majority of the specimens recovered from the Murrindal Limestone differ from Talent's (1956a) original description of *B. westoni* in possessing a thread-like median ridge in the dorsal valve that extends anteriorly to approximately valve midlength. Associated with this ridge are long, thin impressions of muscle scars which extend forward no further than the median ridge (Fig. 22F, G). These two features are highly variable and at any given stratigraphic horizon they range from indistinct to strongly developed. Talent (1963) did not mention the presence or absence of dorsal muscle scars in *B. westoni* from the Buchan Caves Limestone, but he stated that the dorsal valve lacked a median septum. Talent (1963) described *B. westoni?* from the Tabberabbera Formation as possessing elongate muscle scars in the dorsal valve and a variably developed, often faint, median septum.

Buchanathyris has also been recovered from China. *Buchanathyris subplana* (Tien, 1938), from the Devonian of Sichuan Province (Wang et al. 1974) is slightly more elongate, but is not as thick and has a weaker beak and smaller foramen compared to *B. westoni*.

Superfamily NUCLEOSPIROIDEA Davidson, 1881
Family NUCLEOSPIRIDAE Davidson, 1881

Nucleospira Hall in Davidson, 1858b

Type species. By monotypy, Hall in Davidson (1858b: 412); *Spirifer ventricosus* Hall, 1857; Lochkovian of the lower Helderberg Group, Helderberg Mountain, New York, America.

Nucleospira sp. Fig. 22K, L,

Material. Figured material: AM F117334 (Fig. 22K, L): ventral valve from McL 495. Unfigured material: one ventral valve.

Fig. 22. A-J, *Buchanathyris westoni* Talent, 1956a. All specimens x 3. A-E, dorsal, posterior, lateral, ventral and anterior views of articulated specimen, ROC 162, AM F117330. F, dorsal valve interior, ROC 162, AM F117331. G, H, dorsal valve interior and exterior, ROC 165, AM F117332. I, J, ventral valve exterior and interior, ROC 162, AM F117333. K, L, *Nucleospira* sp., ventral valve exterior and interior, McL 495, AM F117334, x 18.

Remarks. It is not possible to assign the Murrindal specimens to a described species of *Nucleospira* due to the limited and inadequately preserved material. However, the shells appear to differ from most other described species of *Nucleospira* in that the median septum of the ventral valve does not extend beyond valve midlength. The Murrindal specimens appear most similar to those described by Philip (1962) from the late Lochkovian Boola Siltstone of the Tyers-Boola area of central Victoria and Talent (1963) from the Pragian Lower Kilgower Member of the Tabberabbera Formation. The Tyers Boola specimens possess a median septum with an ill-defined anterior portion (Philip 1962), whereas the length of the median septum is variable in the Tabberabbera specimens (Talent 1963).

Based on this difference in the length of the median septum alone, the Murrindal specimens may represent a new species of *Nucleospira*. However, most species of *Nucleospira* are very similar externally and internally (Savage 1981). Bowen (1967: 38) and Savage (1981: 366) both stated that new species of *Nucleospira* are assigned primarily on differences in the distinctiveness of the sulcus, valve convexity, the length to width ratio, growth lines and size. It is difficult to determine these characteristics for the Murrindal specimens. In addition, these characteristics appear highly variable both between and within species and the range of variation between species remains unknown (Bowen 1967; Savage 1981). As a result, many workers, such as Johnson (1970a), Harper (1973), Boucot (1973) and Smith (1980), have declined to name individual species.

Order TEREBRATULIDA Waagen, 1883

Remarks. The higher level classification used for the Terebratulida herein follows that of Boucot & Wilson (1994).

Suborder CENTRONELLIDINA Stehli, 1965 Superfamily STRINGOCEPHALOIDEA King, 1850

Family MEGANTERIDAE Schuchert & Levene, 1929

Subfamily ADRENINAE Boucot in Boucot & Wilson, 1994

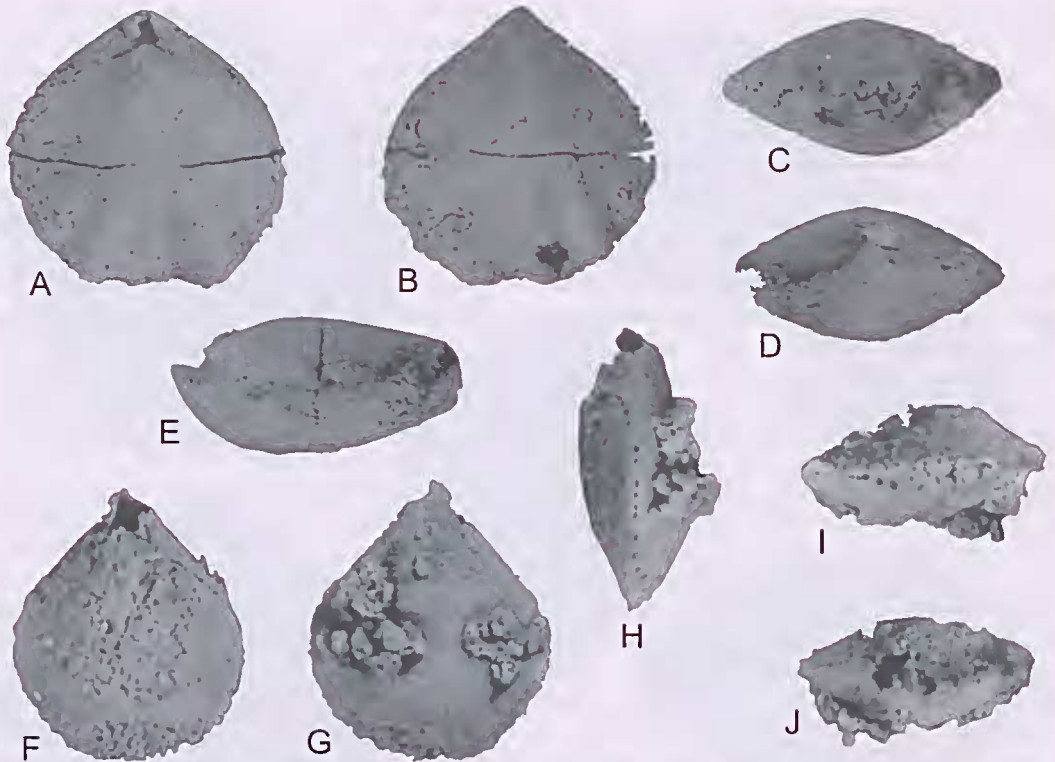


Fig. 23. A-E, *Micidus shandkyddi* Chatterton, 1973, dorsal, ventral, anterior, posterior and lateral views of articulated specimen, ROC 162, AM F117335, x 5. F-J, *Micidus? glaber* Chatterton, 1973, dorsal, ventral, lateral, anterior and posterior views of articulated specimen, McL 497, AM F117336, x 12.

Micidus Chatterton, 1973

Type species. By original designation of Chatterton (1973: 137); *Micidus shandkyddi* Chatterton, 1973; early Emsian 'Receptaculites' Limestone Member, Taemas Limestone, Taemas, New South Wales, Australia.

Micidus shandkyddi Chatterton, 1973

Fig. 23A-E

Micidus shandkyddi gen. et sp. nov. Chatterton 1973: 137, pl. 34, figs 1-12.

?*Micidus?* spp. A. Lenz & Johnson, 1985b: 93, pl. 16, figs 7-24.

?*Micidus?* spp. B Lenz & Johnson 1985b: 93, pl. 16, figs 20, 25-35.

Material. Figured material: AM F117335 (Fig. 23A-E); articulated specimen from ROC 162. Unfigured material: two dorsal valves and 22 articulated specimens.

Description. See Chatterton (1973: 137).

Remarks. Chatterton (1973) separated *M. shandkyddi* from *M? glaber* Chatterton, 1973, primarily on differences in external features. These include the presence of anterolateral plications, a weakly developed fold and sulcus, a weakly sulcate anterior commissure and a submesothyridid (to hypothyridid?) foramen in *M. shandkyddi*. The external features and dimensions of the Murrindal specimens compare well with *M. shandkyddi* from the Emsian 'Receptaculites' Limestone Member, although the Murrindal specimens are slightly larger (Fig. 24). It is not possible to compare internal features though as none of the specimens recovered from the Murrindal Limestone shows any trace of internal preservation.

Lenz & Johnson (1985b) tentatively referred two species from the Pragian Garra Limestone at Wellington to *Micidus* as they possessed simple deltidial plates. *Micidus?* spp. A closely resembles *M. shandkyddi*, both possessing a similar number of

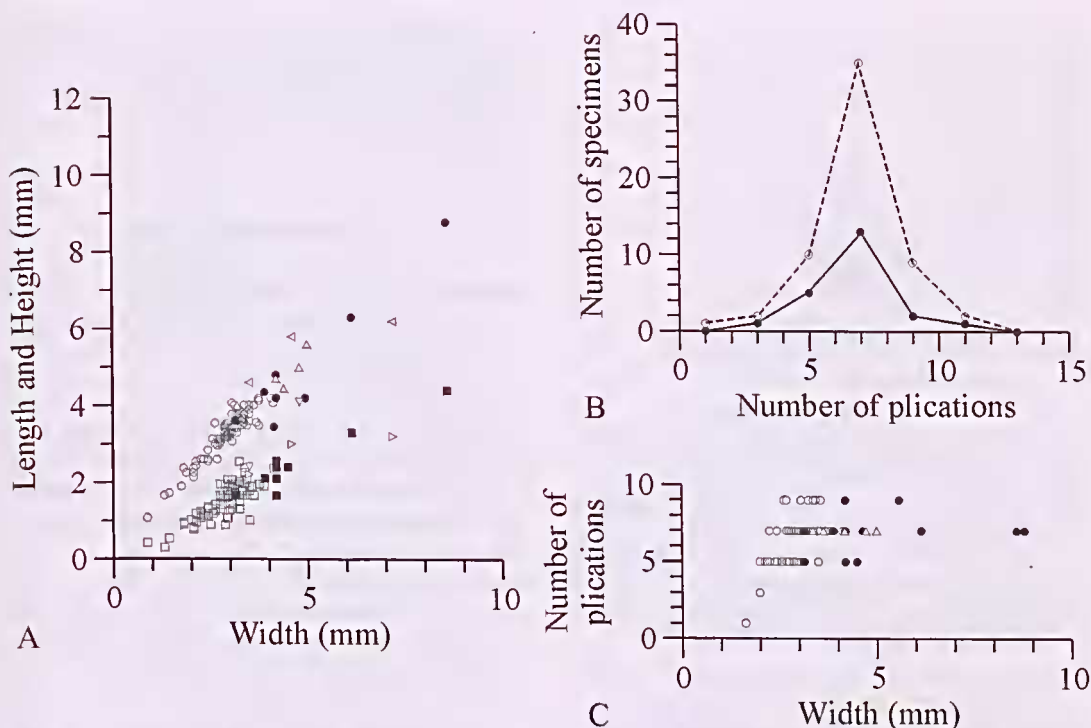


Fig. 24. Comparison of *M. shandkyddi* from the 'Receptaculites' Limestone Member at Taemas (average width 2.87 mm; length 3.22 mm; height 1.5 mm; number of plications 6.9) (Chatterton 1973: fig. 49), with *M. shandkyddi* from the Murrindal Limestone (average width 4.71 mm; length 4.96 mm; height 2.42 mm; number of plications 6.73) and *M. spp. A* from the Garra Formation (average width 4.15 mm; length 4.75 mm; height: 3.25 mm; number of plications 7) (Lenz & Johnson 1985b: pl. 16, figs 7–24) and *M?* spp. B, from the Garra Formation (average width 5.1 mm; length 5.53 mm; height 2.8 mm) (Lenz & Johnson 1985b: pl. 16, figs 20, 25–35). A, Length versus width of ● Murrindal specimens ($n = 8$), ○ Taemas specimens ($n = 72$), △ *M. spp. A* ($n = 4$) and ◁ *M?* spp. B ($n = 3$); height versus width of ■ Murrindal specimens ($n = 10$), □ Taemas specimens ($n = 75$), ▽ *M. spp. A* ($n = 2$) and ▷ *M?* spp. B ($n = 3$). B, Number of specimens versus number of plications of ● Murrindal ($n = 22$) and ○ Taemas specimens ($n = 60$). C, Number of plications versus width of ● Murrindal specimens ($n = 13$), ○ Taemas specimens ($n = 45$) and △ *M. spp. A* ($n = 5$).

plications and dimensions, although they too are somewhat larger than *M. shandkyddi* (Fig. 17). The Garra specimens differ, however, in possessing sharply rounded to angular plications. *Micidus?* spp. B possesses 2–3 pairs of rounded to angular eostae that are at best weakly developed on the anterior half to third of the valve, compared to 5–11 plications on the dorsal valve of *M. shandkyddi*. Despite this external difference from *M. shandkyddi*, Lenz & Johnson (1985b) note that the erural plates and loops of *M?* spp. B are the same as those in *M?* spp. A.

Micidus stellae Soja, 1988, from the Emsian of Kasaan Island, southeastern Alaska, differs in having fewer plications along the anterior margins (three on the dorsal valve and two on the ventral valve) and inner hinge plates that are united anteriomedially.

Micidus? glaber Chatterton, 1973

Fig. 23F–J

Micidus? glaber sp. nov. Chatterton 1973: 138, pl. 30, figs 1–15.

Material. Figured material: AM F117336 (Fig. 23F–J); articulated specimen from MeL 497. Unfigured material: 31 articulated specimens.

Description. See Chatterton (1973: 138).

Remarks. Chatterton (1973) tentatively referred this species from the top of the Emsian 'Receptaculites' Limestone Member to *Micidus* due to internal similarities with *M. shandkyddi*, despite the fact it dif-

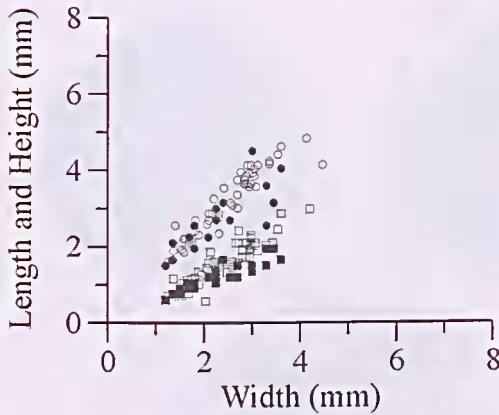


Fig. 25. Comparison of *M? glaber* from the 'Receptaculites' Limestone Member at Taemas (average width 2.51 mm; length 3.19 mm; height 1.65 mm) (Chatterton 1973; fig. 50), with *M? glaber* from the Murrindal Limestone (average width 2.33 mm; length 2.73 mm; height 1.23 mm). Length versus width of ● Murrindal ($n=16$) and ○ Taemas specimens ($n=53$). Height versus width of ■ Murrindal ($n=23$) and □ Taemas specimens ($n=53$).

ferred in lacking plications. The Murrindal specimens closely resemble *M? glaber* externally (Fig. 25). No specimens with internal structures preserved have been recovered from the Murrindal Limestone and the exact taxonomic status of this species must therefore remain doubtful.

Micidus stellae Soja, 1988, from the Emsian of Kasaan Island, southeastern Alaska, is easily distinguished by the presence of three plications developed along the anterior margin of the dorsal valve and two on the ventral valve.

ACKNOWLEDGEMENTS

I am much indebted to Prof. John Talent, Assoc. Prof. Ruth Mawson and Dr. Glenn Broek for making this project available to me and providing support and advice on everything from taxonomy to comments on the final draft. Brett Pyemont and the GEOS 425 Palaeobiology class of 2000 provided support with fieldwork. Michael Engelbretsen assisted with acid leaching and Belinda Kyle helped pick numerous samples. David Matheison and Margaret Anderson provided invaluable assistance with photography and plate making. Dean Oliver skillfully drafted the maps and stratigraphic columns. This manuscript greatly benefited from comments provided by Art Boucot and Tony Wright.

This report is a contribution towards documentation of the brachiopod faunas of the Murrindal Limestone, and to IGCP Project 421: *North Gondwana mid-Palaeozoic bioevent/biogeography patterns in relation to crustal dynamics*.

REFERENCES

- AMSDEN, T. W., 1968. Articulate brachiopods of the St. Clair Limestone (Silurian), Arkansas, and the Clarita Formation (Silurian), Oklahoma. *Paleontographical Society Memoir* 1: 1–117.
- AMSDEN, T. W., 1974. Late Ordovician and Early Silurian articulate brachiopods from Oklahoma, southwestern Illinois and eastern Missouri. *Oklahoma Geological Survey Bulletin* 119: 1–154.
- ALBERTI, G. K. B., 1993. Dacryoconaride und homoetenide Tentaculiten des Unter- und Mittel-Devons I. *Courier Forschungsinstitut Senckenberg* 158: 1–229.
- ALBERTI, G. K. B., 1995. Planktonic tentaculitid correlation with conodont zonation in the south-east Australian Lower Devonian. *Courier Forschungsinstitut Senckenberg* 182: 557–558.
- ALEKSEEVA, R. E., 1960. O novom podrode *Atrypa* (*Desquamatia*) subgen. semevstva Atrypidae Gill (Brachiopody). *Doklady Akademii Nauk SSSR* 131: 421–424.
- ALVAREZ, F. & CARLSON, S. J., 1998. Evolución y relaciones filogenéticas entre los grupos de mayor rango taxonómico de atrídeos y otros "braquiópodos articulados". *Revista Española de Paleontología* 13: 209–234.
- ALVAREZ, F. & COPPER, P. 2002. Uncertain. In *Treatise on Invertebrate Paleontology, part H, Brachiopoda, revised, volume 4: Rhyntonelliformea (part)*, R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Boulder and Lawrence, 1604–1614.
- ALVAREZ, F., RONG JIA-YU & BOUCOT, A. J., 1998. The classification of athyrid brachiopods. *Journal of Paleontology* 72: 827–855.
- ANDERSON, M. M., BOUCOT, A. J. & JOHNSON, J. G., 1969. Eifelian brachiopods from Padaukpin, northern Shan States, Burma. *Bulletin of the British Museum of Natural History (Geology)* 18: 105–163.

- BANCROFT, B. B., 1928. On the notational representation of the rib system in Orthacea. *Memoir and Proceedings of the Manchester Literary and Philosophical Society* 72: 52–90.
- BANCROFT, B. B., 1945. The brachiopod zonal indices of the stages Costonian-Onnian in Britain. *Journal of Paleontology* 19: 181–252.
- BARRANDE, J., 1847. Über die Brachiopoden der silurischen Schichten von Böhmen. *Naturwissenschaftliche Abhandlungen* 1: 357–475.
- BARRANDE, J., 1848. Über die Brachiopoden der silurischen Schichten von Böhmen. *Naturwissenschaftliche Abhandlungen* 2: 155–256.
- BARRANDE, J., 1879. *Système Silurien du centre de la Bohême. Recherches paléontologiques, vol. 5. Classe des Mollusques. Ordre des Brachiopodes*. Published by the author, Prague and Paris, xiv+226 pp.
- BASDEN, A., 1999. Emsian (Early Devonian) microvertebrates from the Buchan and Tamas areas of southeastern Australia. *Records of the Western Australian Museum, Supplement* 57: 15–22.
- BELL, K. N., 1996. Early Devonian (Emsian) agglutinated foraminiferans from Buchan and Bindi, Victoria, Australia. *Proceedings of the Royal Society of Victoria* 108: 73–106.
- BELL, K. N. & WINCHESTER-SEETO, T. M., 1999. Linings of agglutinated foraminifera from the Devonian: taxonomic and biostratigraphic implications. *Journal of Micropalaeontology* 18: 27–43.
- BIERNAT, G., 1959. Middle Devonian Orthoidea of the Holy Cross Mountains and their ontogeny. *Palaontologica Polonica* 10: 1–78.
- BIERNAT, G. & BEDNARCZYK, W., 1990. Evolutionary crisis within the Ordovician aerotretid inarticulate brachiopods of Poland. In *Extinction Events in Earth History*, E. G. Kaufman & O. H. Walliser, eds. *Lecture Notes in Earth History* 30: 105–114.
- BIERNAT, G. & HARPER, D. A. T., 1999. A lingulate brachiopod *Aerotretella*: new data from Ordovician of Poland. *Aeta Palaontologica Polonica* 44: 83–92.
- BOUCOT, A. J., 1973. Early Paleozoic brachiopods of the Moose River Synclinorium, Maine. *United States Geological Survey Professional Paper* 784: 1–81.
- BOUCOT, A. J. & JOHNSON, J. G., 1967. Species and distribution of *Coelospira* (Brachiopoda). *Journal of Paleontology* 41: 1226–1241.
- BOUCOT, A. J., JOHNSON, J. G., PITRAT, C. W. & STATON, R. D., 1965. Spiriferida. In *Treatise on Invertebrate Paleontology, part H, Brachiopoda, volume 2*, R. C. Moore, ed. Geological Society of America and University of Kansas Press, Lawrence, H632–H728.
- BOUCOT, A. J. & WILSON, R. A., 1994. Origin and early radiation of trebratuloid brachiopods: thoughts provoked by *Proensselaeria* and *Nauothyris*. *Journal of Paleontology* 68: 1002–1025.
- BOWEN, Z. P., 1967. Brachiopoda of the Kayser Limestone (Silurian-Devonian) of Maryland and adjacent areas. *Geological Society of America Memoir* 102: 1–103.
- BROCK, G. A., 1989. *Middle Devonian (Givetian) atrypids from the Papilio Formation, north Queensland, Australia*. MSc thesis, Macquarie University, Sydney (unpubl.).
- BROCK, G. A., 2003a. Loehkovian (Early Devonian) brachiopods from the Garra Limestone at Eurimbla, New South Wales, Australia. Part 1: Aerotretida, Strophomenida, Productida, Orthotetida, Orthida and Pentamerida. *Palaontographica Abt. A* 269: 93–136.
- BROCK, G. A., 2003b. Lochkovian (Early Devonian) brachiopods from the Garra Limestone at Eurimbla, New South Wales, Australia. Part 2: Rhynchonellida, Atrypida, Athyrida and Spiriferida. *Palaontographica Abt. A* 270: 49–94.
- BROCK, G. A., ENGELBRETSSEN, M. J. & DEAN-JONES, G., 1995. Acrotretoid brachiopods from the Devonian of Victoria and New South Wales. *Memoirs of the Association of Australasian Palaeontologists* 18: 105–120.
- BROCK, G. A. & TALENT, J. A., 1993. Emsian (Early Devonian) brachiopods from the Ukulunda Beds and Douglas Creek, north Queensland. *Memoirs of the Association of Australasian Palaeontologists* 15: 225–248.
- BRUNTON, C. H. C. & COCKS, L. R. M., 1996. The classification of the brachiopod order Strophomenida. In *Brachiopods*, P. Copper & J. Jin, eds. A.A. Balkema, Rotterdam, 47–51.
- BURROW, C. J. & TURNER, S., 1998. Devonian placoderm scales from Australia. *Journal of Vertebrate Paleontology* 18: 677–695.

- CAMPBELL, K. S. W. & TALENT, J. A., 1967. *Malurostrophia*, a new genus of stropheodontid brachiopod from the Devonian of Australia. *Proceedings of the Royal Society of Victoria* 80: 309–330.
- CARTER, J. L., JOHNSON, J. G., GOURVENNEC, R. & HOU HONG-FEI, 1994. A revised classification of the spiriferid brachiopods. *Annals of the Carnegie Museum* 63: 327–374.
- CASTER, K. E., 1939. A Devonian fauna from Colombia. *Bulletin of American Paleontology* 24: 1–218.
- CHAPMAN, F., 1905. New or little-known Victorian fossils in the National Museum, Melbourne: part VI.—Notes on Devonian spirifers. *Proceedings of the Royal Society of Victoria* 18: 16–19.
- CHAPMAN, F., 1913. New or little-known Victorian fossils in the National Museum, part 16, some Silurian Brachiopoda. *Proceedings of the Royal Society of Victoria* 26: 99–113.
- CHAPMAN, F., 1914. *Australasian fossils*. G. Robertson & Co., Melbourne, 341 pp.
- CHATTERTON, B. D. E., 1973. Brachiopods of the Murrumbidgee Group, Tacmas, New South Wales. *Bureau of Mineral Resources, Geology and Geophysics Bulletin* 137: 1–146.
- CHATTERTON, B. D. E. & PERRY, D. G., 1978. An early Eifelian invertebrate faunule, Whittaker Anticline, northwestern Canada. *Journal of Paleontology* 52: 28–39.
- CHEN XIU-QIN, KUANG GUO-DUN & RONG JIA-YU, 1989. Brachiopods of the Luhui Member of the Dale Formation (late Emsian), Xiangzhou, central Guangxi. *Memoirs of the Nanjing Institute of Geology and Palaeontology* 25: 213–232.
- Chlupáč, I., 1976. The oldest goniatite faunas and their stratigraphical significance. *Lethaia* 9: 303–315.
- COCKS, L. R. M., 1979. New acrotretacean brachiopods from the Palaeozoic of Britain and Austria. *Palaeontology* 22: 93–100.
- COCKS, L. R. M. & RONG JIA-YU, 2000. Strophomenida. In *Treatise on Invertebrate Paleontology, part H, Brachiopoda, revised, volume 2: Linguliformea, Cratiformea, and Rhynchonelliformea (part)*, R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Lawrence, 216–349.
- CONRAD, T. A., 1842. Observations on the Silurian and Devonian systems of the US with descriptions of new organic remains. *Journal of the Academy of Natural Sciences of Philadelphia* 8: 228–280.
- COPPER, P., 1965. A new Middle Devonian atrypid brachiopod from the Eifel of Germany. *Senckenbergiana lethaea* 46: 309–325.
- COPPER, P., 1966a. European Mid-Devonian correlations. *Nature* 209: 982–984.
- COPPER, P., 1966b. The *Atrypa zonata* brachiopod group in the Eifel, Germany. *Senckenbergiana lethaea* 46: 309–325.
- COPPER, P., 1973. *Bifida* and *Kayseria* (Brachiopoda) and their affinity. *Palaeontology* 16: 117–138.
- COPPER, P., 1978. Devonian atrypoids from western and northern Canada. *Geological Association of Canada Special Papers* 18: 289–331.
- COPPER, P., 1986. Filter-feeding and evolution in early spire-bearing brachiopods. In Les Brachiopodes fossiles et actuels, P. R. Racheboeuf & C. C. Emig, eds. *Biostratigraphie du Paléozoïque* 4: 219–230.
- COPPER, P., 1991. Evolution of the atrypid brachiopods. In *Brachiopods Through Time*, D. I. MacKinnon, D. E. Lee & P. J. D. Campbell, eds. A.A. Balkema, Rotterdam, 35–40.
- COPPER, P., 2002. Atrypida. In *Treatise on Invertebrate Paleontology, part H, Brachiopoda, revised, volume 4: Rhynchonelliformea (part)*, R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Boulder and Lawrence, 1377–1474.
- COPPER, P. & GOURVENNEC, R. 1996. Evolution of the spire-bearing brachiopods (Ordovician–Jurassic). In *Brachiopods*, P. Copper & J. Jin, eds. A.A. Balkema, Rotterdam, 81–88.
- DAGYS, A., 1996. On the classification of the order Athyridida. In *Brachiopods*, P. Copper & J. Jin, eds. A.A. Balkema, Rotterdam, 89–90.
- DALMAN, J. W., 1828. Uppställning och Beskrifning af de i Sverige funne Terebratuliter. *Kongliga Svenska Vetenskapsakademien Handlingar for 1827* 3: 85–155.
- DAVIDSON, T., 1858a. A monograph of the British fossil Brachiopoda: Part 5, Carboniferous. *Palaeontographical Society* 5: 1–280.
- DAVIDSON, T., 1858b. Palaeontological notes on the Brachiopoda, no. 1. On genera and sub-

- genera of Brachiopoda that are provided with spiral appendages for the support of the oral arms, and species so constructed, which have been discovered in British Carboniferous strata. *Geologist* 1: 409-416, 457-331.
- DEFRANCE, M. J. L., 1824. *Dictionnaire des Sciences Naturelles* 32: 1-306.
- DE KONINCK, L. G., 1876. Recherches sur les fossiles Paléozoïques de la Nouvelle-Galles du Sud (Australie). *Mémoires du Société Royale des Sciences de Liège* 3: 25-52.
- DE KONINCK, L. G., 1898. Descriptions of the Palaeozoic fossils of New South Wales (Australia). (Translated by T. W. E. David, Mrs David & W. S. Dun from de Koninck 1876). *Memoirs of the Geological Survey of New South Wales, Palaeontology* 6: 1-298.
- D'ORBIGNY, A., 1850. *Prodrome de paléontologie stratigraphie universelle des animaux mollusques et rayonnés*, vol. 1. Victor Mason, Paris, ix+349 pp.
- DROT, J., 1964. Rhynchonelloidea et Spiriferoidea Siluro-Dévonien du Maroc présaharien. *Notes et Mémoires Service Géologique du Maroc* 178: 1-287.
- DUN, W. S., 1904. Notes on some new species of Palaeozoic Brachiopoda from New South Wales. *Records of the Geological Survey of New South Wales* 7: 318-325.
- ERBEN, H. K., 1960. Primitive Ammonoidea aus dem Unterdevon Frankreichs und Deutschlands. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 110: 1-128.
- ERBEN, H. K., 1962. Unterlagen zur Diskussion der Unter/Mitteldevon-Grenze. In *Symposium-Band der 2. Internationalen Arbeitstagung über die Silur/Devon-Grenze und die stratigraphie des Silurs und des Devons (1960)* 315: 62-70.
- ERBEN, H. K., 1964. Die Evolution der ältesten Ammonoidea (Lieferung I). *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 120: 107-212.
- ERBEN, H. K., 1965. Die Evolution der ältesten Ammonoidea (Lieferung II). *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 122: 275-312.
- FARRELL, J. R., 1992. The Garra Formation (Early Devonian: late Lochkovian) between Cumnoek and Larras Lee, New South Wales, Australia: stratigraphic and structural setting, faunas and community sequence. *Palaeontographica Abt. A* 222: 1-41.
- FICHNER, F. & Havlíček, V., 1978. Middle Devonian brachiopods from Čelechovice, Moravia. *Sborník geologických věd palaeontologie* 21: 49-106.
- FOERSTE, A. F., 1917. Notes on Silurian fossils from Ohio and other central states. *Ohio Journal of Science* 17: 233-268.
- FÖLDVARY, G. Z., 2000. Siluro-Devonian invertebrate faunas from the Bogan Gate-Trundle-Mineral Hill area of central New South Wales. *Records of the Western Australian Museum, Supplement* 58: 81-102.
- GEORGE, T. N., 1931. Amboocoelia Hall and certain similar British Spiriferidae. *Quarterly Journal of the Geological Society of London* 87: 30-61.
- GILL, E. D., 1950. Preliminary account of the palaeontology and palaeoecology of the Eldon Group Formations of the Zeehan area, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 1949: 231-258.
- GILL, E. D., 1951. Two new brachiopod genera from Devonian rocks in Victoria. *Memoirs of the National Museum, Melbourne* 17: 187-205.
- GIRTY, G. H., 1904. New molluscan genera from the Carboniferous. *United States National Museum Proceedings* 27: 721-736.
- GOLDFUSS, A., 1839. Beiträge zur Petrefactenkunde. *Verhandlungen der Kaiserlichen Leopoldinisch-Carolinischen der Naturforscher* 19: 327-364.
- GRATSIANOVA, R. T., 1974. "Shukhertelly" rannego i srednego devona na yuge zapadnoi Sibiri: sistematičeskaja prikladnaja znanost', elementy ekologii stratigrafičeskoj značenie. In *Sreda i žizn' v geologičeskom prošlom (paleoekologičeskiye problemy)*, O. A. Betekhitina & I. T. Zhuravleva, eds *Akademiia Nauk SSSR, Sibirskoe Otdelenie, Institut Geologii i Geofiziki (IGIG)*, Trudy 84: 77-87.
- GÜRICH, G., 1896. Das Paläozoicum Polniseiten Mittelgebirge. *Verhandlungen der Russisch-Kaiserliche Mineralogische Gesellschaft zu St. Petersburg* 32: 1-539.
- HALL, J., 1843. Survey of the fourth geological district. *Natural history of New York, Geology*, vol. 4. Carroll & Albany, Albany, ix+525 pp.

- HALL, J., 1857. Descriptions of new species of Palaeozoic fossils from the Lower Helderberg, Oriskany Sandstone, Upper Helderberg, Hamilton and Chemung Groups. *New York State Cabinet of Natural History 10th Annual Report*: 41–186.
- HALL, J., 1859a. Observations on genera of Brachiopoda. Contributions to the palaeontology of New York. *New York State Cabinet of Natural History 12th Annual Report* 8–110.
- HALL, J., 1859b. Containing descriptions and figures of the organic remains of the Lower Helderberg Group and the Oriskany Sandstone. *Natural History of new York, Palaeontology* 3: 1–532.
- HALL, J., 1860. Descriptions of new species of fossils, from the Hamilton group of western New York, with notices of others from the same horizon in Iowa and Indiana. *New York State Cabinet of Natural History 13th Annual Report* 76–94.
- HALL, J., 1863. Contributions to palaeontology. *16th Annual Report of the Regents of the University of the State of New York on the condition of the State Cabinet of Natural History*: 3–226.
- HALL, J. & CLARKE, J. M., 1892. An introduction to the study of the genera of Palaeozoic Brachiopoda. *Palaeontology of New York* 8: 1–367.
- HALL, J. & CLARKE, J. M., 1893. An introduction to the study of the genera of Palaeozoic Brachiopoda. *Palaeontology of New York* 8: 1–317.
- HALL, J. & CLARKE, J. M., 1894. An introduction to the study of the Brachiopoda, intended as a handbook for the use of students. *Thirteenth Annual Report of the New York State Geologist for the Year 1893, Palaeontology* 2: 751–943.
- HARPER, C. W., 1973. Brachiopods of the Arisaig Group (Silurian-Lower Devonian) of Nova Scotia. *Geological Survey of Canada Bulletin* 215: 1–163.
- HARPER, C. W. & BOUCOT, A. J., 1978a. The Strophodontacea, part I: Leptostrophidae, Eostrophodontidae and Strophonellidae. *Palaeontographica Abt. A* 161: 55–118.
- HARPER, C. W. & BOUCOT, A. J., 1978b. The Strophomenacea, part II: Douvillinidae, Telacoshaleriidae, Amphistrophidae and Shaleriidae. *Palaeontographica Abt. A* 161: 119–175.
- HARPER, C. W., JOHNSON, J. G. & BOUCOT, A. J., 1967. The Pholidostrophinae (Brachiopoda; Ordovician, Silurian, Devonian). *Senckenbergiana lethaea* 48: 403–461.
- HARPER, D. A. T., 2000. Dalmanellidina. In *Treatise on Invertebrate Paleontology, part H, Brachiopoda, revised, volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (part)*. R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Boulder and Lawrence, 782–844.
- Havlíček, V., 1953. O několika nových ramenonožcích českého a moravského středního devonu. *Věstník Ústředního ústavu geologického* 28: 4–9.
- Havlíček, V., 1956. Ramenonožci vapeneu branických a hluboepejských z nejbližšího prazského okolí. *Sborník Ústředního ústavu geologického* 22: 535–665.
- Havlíček, V., 1959a. Rhynchonelloidea des böhmischen älteren Paläozoikums (Brachiopoda). *Rozpravy Ústředního ústavu geologického* 27: 1–211.
- Havlíček, V., 1959b. Spiriferidae v českém siluru a devonu (Brachiopoda). *Rozpravy Ústředního ústavu geologického* 25: 1–219.
- Havlíček, V., 1967. Brachiopoda of the suborder Strophomenidina in Czechoslovakia. *Rozpravy Ústředního ústavu geologického* 33: 1–235.
- Havlíček, V., 1975. New genera and species of Orthida (Brachiopoda). *Věstník Ústředního ústavu geologického* 50: 231–235.
- Havlíček, V., 1977. Brachiopods of the order Orthida in Czechoslovakia. *Rozpravy Ústředního ústavu geologického* 44: 1–327.
- HILL, D., 1950. Middle Devonian corals from the Buchan district, Victoria. *Proceedings of the Royal Society of Victoria* 62: 137–164.
- HILL, D., PLAYFORD, G. & WOODS, J. T., 1967. *Devonian Fossils of Queensland*. Queensland Palaeontographical Society, Brisbane, 32 pp.
- HOLLOWAY, D. J., 1996. New Early Devonian styginid trilobites from Victoria, Australia, with revision of some spinose styginids. *Journal of Paleontology* 70: 428–438.
- HOLMER, L. E. & POPOV, L. E. 2000. Lingulata. In *Treatise on Invertebrate Paleontology,*

- part H, *Brachiopoda, revised, volume 2: Linguliformea, Craniiformea, and Rhynchonelliformea (part)*, R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Boulder and Lawrence, 30–146.
- HOU HONG-FEI & XIAN SI-YUAN, 1975. The Lower and Middle Devonian brachiopods from Guangxi and Guizhou. *Professional Papers of Stratigraphy and Palaeontology* 1: 1–85.
- HOUSE, M. R., 1979. Biostratigraphy of the early Ammonoidea. In *The Devonian System*, M. R. House, C. T. Scrutton & M. G. Bassett, eds. *Special Papers in Palaeontology* 23: 263–280.
- HOWITT, A. W., 1876. Notes on the Devonian rocks of northern Gippsland. *Geological Survey of Victoria, Progress Report* 3: 181–249.
- ICZN, 1956. Opinion 420. Addition to the "Official List of Specific Names in Zoology" of the specific names for eleven species of the Class Brachiopoda and for 2 species of the Class Cephalopoda originally published by Martin (W.) in 1809 in the nomenclatorially invalid work entitled "Petrificata Derbiensia" and now available as from the first subsequent date on which they were severally published in conditions satisfying the requirements of the "Regles". *Opinions and Declarations Rendered by the International Commission on Zoological Nomenclature* 14: 131–167.
- JOHNSON, J. G., 1970a. Great Basin Lower Devonian Brachiopoda. *Memoir of the Geological Society of America* 121: 1–421.
- JOHNSON, J. G., 1970b. Early Middle Devonian brachiopods from central Nevada. *Journal of Paleontology* 44: 252–264.
- JOHNSON, J. G., 1971. Some new and problematical brachiopods from the Lower Devonian of Nevada. *Journal of Paleontology* 45: 95–99.
- JOHNSON, J. G., 1974a. Middle Devonian Givetian brachiopods from the *Leiorhynchus castanea* Zone of Nevada. *Geologica et Palaeontologica* 8: 49–96.
- JOHNSON, J. G., 1974b. Affinity of Dayiacean brachiopods. *Palaeontology* 17: 437–439.
- JOHNSON, J. G. & BOUCOT, A. J., 1968. External morphology of *Anatrypa* (Devonian, Brachiopoda). *Journal of Paleontology* 42: 1205–1207.
- JOHNSON, J. G., BOUCOT, A. J. & MURPHY, M. A., 1973. Pridolian and Early Gedinnian age brachiopods from the Roberts Mountains Formation of Central Nevada. *University of California Publications in Geological Science* 100: 1–75.
- JOHNSON, J. G. & TALENT, J. A., 1967. *Muriferella*, a new genus of Lower Devonian septate Dalmanellid. *Proceedings of the Royal Society of Victoria* 80: 43–50.
- JOHNSTON, P. A., 1993. Lower Devonian Pelecypoda from southeastern Australia. *Memoirs of the Association of Australasian Palaeontologists* 14: 1–134.
- KAESLER, R. L. ed., 2000. *Treatise on Invertebrate Palaeontology, part H, Brachiopoda, revised, volumes 2–3: Linguliformea, Craniiformea, and Rhynchonelliformea (part)*. Geological Society of America and University of Kansas Press, Boulder and Lawrence, xxx+ii+919 pp.
- KAESLER, R. L. ed., 2002. *Treatise on Invertebrate Palaeontology, Part H, Brachiopoda, revised, volume 4: Rhynchonelliformea (part)*. Geological Society of America and University of Kansas Press, Boulder and Lawrence, xxxix+767 pp.
- KAPLUN, L. I. & KRUPCHENKO, N. V., 1991. Brachipody nizhnego i srednego devona Dzhungaro-Balkhashskoi provintsii. In *Biostratigrafiia nizhnego i srednego devona Dzhungaro-Balkhashskoi provintsii*, V. N. Dubatolov & G. A. Stukalina, eds. Nauka, Novosibirsk, 111–147.
- KAYSER, E., 1871. Die Brachiopoden aus Mittel- und Ober-Devon der Eifel. *Zeitschrift der Deutschen Geologischen Gesellschaft* 23: 491–647.
- KOZLOWSKI, R., 1929. Les brachiopodes gothlandiens de la Podolie Polonaise. *Palaeontologica Polonica* 1: 1–254.
- KOZLOWSKI, R., 1946. *Howellella*, a new name for *Crispella* Kozłowski, 1929. *Journal of Paleontology* 20: 295.
- KRAUSE, F. F. & ROWELL, A. J., 1975. Distribution and systematics of the inarticulate brachiopods of the Ordovician carbonate mud mound of Meiklejohn Peak, Nevada. *University of Kansas Paleontological Contributions Paper* 61: 1–74.
- LAMARCK, J. B. P., 1819. *Historie Naturelle des Animaux sans Vertèbres, part 1. Brachiopoda*. J. B. Baillière, Paris, 735 pp.

- LENZ, A. C., 1977a. Upper Silurian and Lower Devonian brachiopods of Royal Creek, Yukon, Canada. Part 1: Orthoidea, Strophomenida, Pentamerida, Rhynchonellida. *Palaeontographica Abt. A* 159: 37–109.
- LENZ, A. C., 1977b. Upper Silurian and Lower Devonian brachiopods of Royal Creek, Yukon, Canada. Part 2: Spiriferida: Atrypacea, Dayiaea, Athyridacea, Spiriferacea. *Palaeontographica Abt. A* 159: 111–138.
- LENZ, A. C. & JOHNSON, B. D., 1985a. Brachiopods of the Garra Formation (Lower Devonian), Wellington area, New South Wales, Australia: Orthoidea, Strophomenida, Pentamerida. *Palaeontographica Abt. A* 188: 35–70.
- LENZ, A. C. & JOHNSON, B. D., 1985b. Brachiopods of the Garra Formation (Lower Devonian), Wellington area, New South Wales, Australia: Rhynchonellida, Spiriferida, Terebratulida. *Palaeontographica Abt. A* 188: 71–104.
- LONG, J. A., 1984. New Placoderm fishes from the Early Devonian Buchan Group, eastern Victoria. *Proceedings of the Royal Society of Victoria* 96: 173–186.
- LONG, J. A., 1986. New ischnacanthid acanthodians from the Early Devonian of Australia, with comments on acanthodian interrelationships. *Zoological Journal of the Linnean Society* 87: 321–339.
- LUDVIGSEN, R., 1974. A new Devonian aerotretid (Brachiopoda, Inarticulata) with unique protegular ultrastructure. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte* 3: 133–148.
- MAURER, F., 1889. Palaeontologische studien in gebeit des Rheinischen Devon. 8 Mitteilungen über fauna gliederung des Rechtsrheinischen Unterdevon. *Neues Jahrbuch für Mineralogie Abhandlungen* 2: 1–160.
- MAWSON, R., 1987. Early Devonian conodont faunas from Buchan and Bindi, Victoria, Australia. *Palaeontology* 30: 251–297.
- MAWSON, R. & TALENT, J. A., 1999. Early Devonian (Lochkovian) brachiopods from Windellama, southeastern Australia. *Senckenbergiana lethaea* 79: 145–189.
- MAWSON, R. & TALENT, J. A., 2000. The Devonian of eastern Australia: stratigraphic alignments, stage and series boundaries, and the transgression-regression pattern re-considered. In Subcommission on Devonian stratigraphy: recognition of Devonian series and stage boundaries in geological areas, P. Bultynck, ed. *Courier Forschungsinstitut Senckenberg* 225: 243–270.
- MAWSON, R., TALENT, J. A., BEAR, V. C., BENSON, D. S., BROCK, G. A., FARRELL, J. R., HYLAND, K. A., PYEMONT, B. D., SLOAN, T. R., SORENTINO, L., STEWART, M. I., TROTTER, J. A., WILSON, G. A. & SIMPSON, A. G., 1988. Conodont data in relation to resolution of stage and zonal boundaries for the Devonian of Australia. In Devonian of the world; proceedings of the second international symposium on the Devonian System; volume III, paleontology, paleoecology and biostratigraphy, N. J. McMillan, A. F. Embry & D. J. Glass, eds. *Memoir of the Canadian Society of Petroleum Geologists* 14: 485–527.
- MAWSON, R., TALENT, J. A., BROCK, G. A. & ENGBRETSSEN, M. J., 1992. Conodont data in relation to sequences about the Pragian-Emsian boundary (Early Devonian) in southeastern Australia. *Proceedings of the Royal Society of Victoria* 104: 23–56.
- MCCOY, F., 1867. On the recent zoology and palaeontology of Victoria. *Annals and Magazine of Natural History* 20: 175–202.
- MCCOY, F., 1876. *Prodromus of the Palaeontology of Victoria* Decade 4: 15–20.
- MERGL, M., 2001. Lingulate brachiopods of the Silurian and Devonian of the Barrandian (Bohemia, Czech Republic). *Acta Musei Nationalis Pragae, Series B, Historia Naturalis* 57: 1–49.
- MITCHELL, J. & DUN, W. S., 1920. The Atrypidae of New South Wales, with reference to those recorded from other states of Australia. *Proceedings of the Linnean Society of New South Wales* 45: 266–276.
- MUIR-WOOD, H. M., 1925. Notes on the Silurian brachiopod genera *Delthyris*, *Uncinulina*, and *Meristina*. *Annals and Magazine of Natural History* 15: 83–95.
- MUIR-WOOD, H. M., 1962. *On the morphology and classification of the brachiopod suborder Chonetoida*. British Museum (Natural History), London, viii+132 pp.

- MURCHISON, R. I., 1839. *The Silurian system founded on geological researches in the counties of Salop, Hereford, Radnor, Montgomery, Caerthmarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and Stafford: with descriptions of the coalfields and overlying formations*. John Murray Publishers, London, xxxiii+768 pp.
- PAJCHŁOWA, M., 1957. Dewon w profilu Grzegorzowice-Skaly. *Biuletyn Instytutu Geologicznego* 122: 145–254.
- PARFREY, S. M., 1989. Early Devonian fossils from the Ukalunda Beds northwest of Mount Coolon, central Queensland. *Queensland Government Mining Journal* 90: 20–21.
- PERRY, D. G., 1979. Late Early Devonian reef associated brachiopods of the Prongs Creek Formation, northern Yukon. *Journal of Paleontology* 53: 1094–1111.
- PERRY, D. G., 1984. Brachiopoda and biostratigraphy of the Silurian-Devonian Delorme Formation in the district of Mackenzie, the Yukon. *Royal Ontario Museum Life Science Contributions* 138: 1–243.
- PHILIP, G. M., 1962. The palaeontology and stratigraphy of the Siluro-Devonian sediments of the Tyers area, Gippsland, Victoria. *Proceedings of the Royal Society of Victoria* 75: 123–246.
- PHILIP, G. M., 1966. Lower Devonian conodonts from the Buchan Group, eastern Victoria. *Micropaleontology* 12: 441–460.
- PHILIP, G. M. & PEDDER, A. E. H., 1964. A re-assessment of the age of the Middle Devonian of south-eastern Australia. *Nature* 202: 1323–1324.
- POPOV, L. E. 1981a. Pervaja nakhodka bez-zamkovykh brachiopod semeistva Aerotretidae v nizhnem devone SSSR. In *Paleontologicheskii osnovna stratigraficheskikh skliem paleozoi mezozoi ostrovo Sovetskoi Arktiki*, V. I. Bondarev, ed. Leningrad, 61–65.
- POPOV, L. E. 1981b. Pervaja nakhodka mikroskopicheskikh bezzamkovykh brachiopod semeistva Aerotretidae v silure Estonii. *Eesti NSV Teaduste Akadeemia Toimetised (Geologia)* 30: 34–41.
- POPOV, L. E., NÖLVAK, J. & HOLMER, L. E., 1994. Late Ordovician lingulate brachiopods from Estonia. *Palaentology* 37: 627–650.
- PUSCH, G. G., 1833. *Geognostische Beschreibung von Polen, so wie der übrigen Nordkarpathen-Länder. Part 1*. Stuttgart & Tübingen, 338 pp.
- PYEMONT, B. D., 1990. *Conodont faunal succession through the Murrindal Limestone, Buchan area, Victoria*. MSE thesis, Macquarie University, Sydney (unpubl.).
- QUENSTEDT, F. A., 1868–1871. Petrefactenkunde Deutschlands. *Die Brachiopoden* 2: 1–748.
- RACHEBOEUF, P. R., 1987. Upper Lower and lower Middle Devonian chonetacean brachiopods from Bathurst, Devon and Ellesmere Islands, Canadian Arctic Archipelago. *Geological Survey of Canada Bulletin* 375: 1–29.
- REED, F. R. C., 1908. The Devonian faunas of the northern Shan States. *Palaentologica Indica* 2: 1–183.
- RONG JIA-YU & COCKS, L. R. M., 1994. True Strophomena and a revision of the classification and evolution of strophomenoid and 'strophodontoid' brachiopods. *Palaentology* 37: 651–694.
- RZIIONSITSKAYA, M. A., 1975. Biostratigraphia devona okrain Kuznetskogo basseina. Tom 2: Opisani brachiopod, Chast' 1: Pentamerida i Atrypida. *Trudy Vsesoiuznyi Ordena Lenina Nauchno-issledovatel'skii Geologicheskii Institut* 244: 1–232.
- SAVAGE, N. M., 1968. Planicardinia, a new septate dalmanellid brachiopod from the Devonian of New South Wales. *Palaentology* 11: 627–632.
- SAVAGE, N. M., 1969. New spiriferid brachiopods from the Lower Devonian of New South Wales. *Palaentology* 12: 472–487.
- SAVAGE, N. M., 1971. Brachiopods from the Lower Devonian Mandagery Park Formation, New South Wales. *Palaentology* 14: 387–422.
- SAVAGE, N. M., 1974. The brachiopods of the Lower Devonian Maradana Shale, New South Wales. *Palaentographica Abt. A* 146: 1–51.
- SAVAGE, N. M., 1981. A reassessment of the age of some Paleozoic brachiopods from south-eastern Alaska. *Journal of Paleontology* 55: 353–369.
- SCHINDEWOLF, O. H., 1932. Zur Stammesgeschichte der Ammoneen. *Paläontologische Zeitschrift* 14: 164–181.

- SCHNUR, J. 1853. Zusammenstellung und Beschreibung sämtlicher im Übergangsgebirge der Eifel vorkommenden Brachiopoden, nebst Abbildungen Derselben. *Palaeontographica* 3: 169–257.
- SCHUCHERT, C. & COOPER, G. A., 1931. Synopsis of the brachiopod genera of the suborders Orthoidea and Pentamerioidea, with notes on the Telotremata. *American Journal of Science (Series 5)* 22: 214–255.
- SCHUCHERT, C. & COOPER, G. A., 1932. Brachiopod genera of the suborders Orthoidea and Pentamerioidea. *Memoirs of the Peabody Museum of Natural History* 4: 1–270.
- SELWYN, A. R. C. & ULRICH, G. H. F., 1867. Notes on the physical geography, geology and mineralogy of Victoria. *Intercolonial Exhibition of Australasia, Melbourne 1866–67* 3: 147–235.
- SHERWIN, L., 1995. Siluro-Devonian brachiopods from the Amphitheatre and Winduek Groups (Cobar Supergroup), western New South Wales. *Memoirs of the Association of Australasian Palaeontologists* 18: 61–96.
- SMITH, R. E., 1980. Lower Devonian (Lochkovian) biostratigraphy and brachiopod faunas, Canadian Arctic Islands. *Geological Survey of Canada Bulletin* 308: 1–155.
- SOJA, C. M., 1988. Lower Devonian (Emsian) brachiopods from southeastern Alaska, U.S.A. *Palaeontographica Abt. A* 201: 129–193.
- SOWERBY, J., 1822. *The mineral conchology of Great Britain*, vol. 4. Published by the author, London, 114 pp.
- SPRIESTERSBACK, J. & FUCHS, A., 1909. Die fauna der Renscheider Schichten. *Abhandlungen Preussischen Geologischen Landesanstalt* 58: 1–81.
- STRUSZ, D. L., 1982. Wenlock brachiopods from Canberra, Australia. *Alcheringa* 6: 105–142.
- STRUSZ, D. L., 1990. Catalogue of type, figured and cited specimens in the Commonwealth palaeontological collection: Brachiopoda. *Bureau of Mineral Resources, Geology and Geophysics Report* 298: 1–289.
- STRUSZ, D. L., 2000. Revision of the Silurian and Early Devonian ebonetoidean brachiopods of southeastern Australia. *Records of the Australian Museum* 52: 245–287.
- STRUSZ, D. L., CHATTERTON, B. D. E. & FLOOD, P. G., 1970. Revision of the New South Wales Devonian Brachiopod 'Spirifer' *yassensis*. *Proceedings of the Linnean Society of New South Wales* 95: 170–190.
- SUSSMILCH, C. A., 1914. *An Introduction to the Geology of New South Wales*, 2nd edn. Angus & Robertson, Sydney, 296 pp.
- SUSSMILCH, C. A., 1922. *An Introduction to the Geology of New South Wales*, 3rd edn. Angus & Robertson, Sydney, 296 pp.
- TALENT, J. A., 1956a. Devonian brachiopods and pelecypods of the Buchan Caves Limestone, Victoria. *Proceedings of the Royal Society of Victoria* 68: 1–56.
- TALENT, J. A., 1956b. Siluro-Devonian brachiopods from Marble Creek, Thompson River, Victoria. *Proceedings of the Royal Society of Victoria* 68: 73–84.
- TALENT, J. A., 1963. The Devonian of the Mitchell and Wentworth Rivers. *Memoirs of the Geological Survey of Victoria* 24: 1–118.
- TALENT, J. A., 1965a. The stratigraphic and diastrophic evolution of central and eastern Victoria in Middle Palaeozoic times. *Proceedings of the Royal Society of Victoria* 79: 175–195.
- TALENT, J. A., 1965b. The Silurian and Early Devonian faunas of the Heathcote District, Victoria. *Memoirs of the Geological Survey of Victoria* 26: 1–55.
- TALENT, J. A., 1969. The geology of east Gippsland. *Proceedings of the Royal Society of Victoria* 82: 37–60.
- TALENT, J. A., GRATSIANOVA, R. T. & YOLKIN, E. A., 2001. Latest Silurian (Pridoli) to Middle Devonian of the Asia-Australia hemisphere: rationalization of brachiopod taxa and faunal lists; correlation charts. *Courier Forschungsinstitut Senckenberg* 236: 1–221.
- TALENT, J. A., MAWSON, R., AITCHISON, J. C., BECKER, R. T., BELL, K. N., BRADSHAW, M. A., BURROW, C. J., COOK, A. G., DARGAN, G. M., DOUGLAS, J. G., EDGECOMBE, G. D., FEIST, M., JONES, P. J., LONG, J. A., PHILLIPS-ROSS, J. R., PICKETT, J. W., PLAYFORD, G., RICKARDS, R. B., WEBBY, B. D., WINCHESTER-SEETO, T., WRIGHT, A. J., YOUNG, G. C. & ZHEN YONG-YI, 2000. Devonian palaeobiogeography of Australia and adjoining regions. In *Palaeobio-*

- geography of Australasian faunas and floras, A. J. Wright, G. C. Young, J. A. Talent & J. R. Laurie, eds. *Memoir of the Association of Australasian Palaeontologists* 23: 167–257.
- TEICHERT, C., 1948. Middle Devonian goniatites from the Buchan district, Victoria. *Journal of Palaeontology* 22: 60–67.
- TEICHERT, C. & TALENT, J. A., 1958. Geology of the Buchan area, east Gippsland. *Memoirs of the Geological Survey of Victoria* 21: 1–52.
- TIEN, C. C., 1938. Devonian Brachiopoda of Hunan. *Palaeontologia Sinica* 4: 1–192.
- VALENTINE, J. L., BROCK, G. A. & MOLLOY, P. D., 2003. Linguliformean brachiopod faunal turnover across the Ireviken Event (Silurian) at Boree Creek, central-western New South Wales, Australia. *Conrrier Forschungsinstitut Senckenberg* 242: 301–327.
- VANDERCAMMEN, A., 1963. Spiriferidae du Dévonien de la Belgique. *Institut Royal des Sciences Naturelles de Belgique, Mémoires* 150: 1–179.
- VEEVERS, J. J., 1959. Devonian brachiopods from the Fitzroy Basin, Western Australia. *Bureau of Mineral Resources, Geology and Geophysics Bulletin* 45: 1–220.
- VON BITTER, P. H. & LUDVIGSEN, R., 1979. Formation and function of protegular pitting in some North American acrotretid brachiopods. *Palaeontology* 22: 705–720.
- VON MEYER, H., 1831. Beschreibung des *Orthoceratites striolatus* und über den bau und das Vorkommen einiger vielkammeriger fossiler Cephalopoden, nebst Beschreibung von *Calymene aequalis*. *Vernhandlungen der Leopoldinisch-Carolinisch Akademie der Naturforschende* 15: 59–112.
- WALCOTT, C. D., 1884. Paleontology of the Eureka District. *United States Geological Survey Monographs* 8: 1–298.
- WALLACE, M., 1987. The role of internal erosion and sedimentation in the formation of stromatolite mudmounds and associated lithologies. *Journal of Sedimentary Petrology* 57: 695–700.
- WALMSLEY, V. G. & BOUCOT, A. J., 1971. The Resserellinae—a new subfamily of Late Ordovician to Devonian dalmanellid brachiopods. *Palaeontology* 14: 487–531.
- WALMSLEY, V. G. & BOUCOT, A. J., 1975. The phylogeny, taxonomy and biogeography of Silurian and Early to mid-Devonian Isorthinae (Brachiopoda). *Palaeontographica Abt. A* 148: 34–108.
- WANG YÜ, 1956. Some new brachiopods from the Yükiang Formation of Southern Kwangsi Province. *Scientia Sinica* 5: 373–388.
- WANG YÜ & RONG JIA-YU, 1986. Early Emsian (Devonian) brachiopods of the Nanning-Liujing district, central Guangxi, southern China. *Palaeontologia Sinica* 172: 1–282.
- WANG YÜ, RONG JIA-YU & CHIEN XIU-QIN, 1987. Early late Emsian brachiopods from Dale, Xiangzhou, Guangxi. *Memoirs of the Nanjing Institute of Geology and Palaeontology* 23: 121–146.
- WANG YÜ, YÜ CHIANG-MING & WU QI, 1974. Advances in the Devonian biostratigraphy of south China. *Memoirs of the Nanjing Institute of Geology and Palaeontology* 6: 1–71.
- WEBBY, B. D., STEARN, C. W. & ZIEN YONG-YI, 1993. Lower Devonian (Pragian-Emsian) stromatoporooids from Victoria. *Proceedings of the Royal Society of Victoria* 105: 113–185.
- WHITEHOUSE, F. W., 1929. Preliminary report on Devonian fossils from the districts of Mt Wyatt and Ukalunda. *Queensland Government Mining Journal* 30: 158–159.
- WILLIAMS, A. & BRUNTON, C. H., 1993. Role of shell structure in the classification of the orthotetid brachiopods. *Palaeontology* 36: 931–966.
- WILLIAMS, A. & HARPER, D. A. T., 2000. Orthida. In *Treatise on Invertebrate Paleontology: part H, Brachiopoda, revised, volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (part)*, R. L. Kaesler, ed. Geological Society of America and University of Kansas Press, Boulder and Lawrence, 714–844.
- WINCHESTER-SEETO, T. M., 1996. Emsian Chitinozoa from the Buchan area of southeastern Australia. *Acta Palaeontologica Polonica* 41: 149–230.
- WINCHESTER-SEETO, T. M. & PARIS, F., 1989. Preliminary investigations of some Devonian (Lochkovian-Eifelian) chitinozoans from eastern Australia. *Alcheringa* 13: 167–173.

XU HAN-KUI, 1987. Lower Devonian brachiopods from Xainza, northern Xizang. *Bulletin of the Nanjing Institute of Geology and Palaeontology* 11: 21-62.

ZHANG NING, 1989. Wenlockian (Silurian) brachiopods of the Cape Phillips Formation, Baillie Hamilton Island, Arctic Canada: part 1. *Palaeontographica Abt. A* 206: 49-97.